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THE THEORY OF INTERNAL STRESS IN GRAPHICAL STATICS.

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Written for VAN NOSTRAND'S MAGAZINE.

I.

STRESS includes all action and reaction of bodies and parts of bodies by attraction of gravitation, cohesion, electric repulsion, contact, etc., viewed especially as distributed among the particles composing the body or bodies. Since action and reaction are necessarily equal, stress is included under the head of Statics, and it may be defined to be the equilibrium of distributed forces.

Internal stress may be defined as the action and reaction of molecular forces. Its treatment by analytic methods is necessarily encumbered by a mass of formulæ which is perplexing to any except an expert mathematician. It is necessarily so encumbered, because the treatment consists in a comparison of the stresses acting upon planes in various directions, and such a comparison involves transformation of quadratic functions of two or three variables, so that the final expressions contain such a tedious array of direction cosines that even the mathematician dislikes to employ them.

Now, since the whole difficulty really lies in the unsuitability of Cartesian coordinates for expressing relations which are dependent upon the parallelogram of forces, and does not lie in the relations themselves, which are quite simple, and, which no doubt, can be made to appear so in quaternion or other suitable notation; it has been thought by the writer that a presentation of the subject from a graphical stand point would put the entire investigation within the reach of any one who might wish to understand it, and would also be of assistance to those who might wish to read the analytic investigation.

The treatment consists of two principal parts: in the first part the inherent properties of stress are set forth and proved by a general line of reasoning which entirely avoids analysis, and which, it is hoped, will make them well understood; the second part deals with the problems which arise in treating stress. These problems are solved graphically, and if analytic expressions are given for these solutions, such expressions will result from elementary considerations appearing in the graphical solutions. The constructions by which the solutions are obtained are many of them taken from the works of the late Professor Rankine, who employed them principally as illustrations,

and as auxiliary to his analytic investigations.

It is thus proposed to render the treatment of stress exclusively graphical, and by so doing to add a branch to the science of Graphical Statics, which has not heretofore been recognized as susceptible of graphical treatment. It seems unnecessary to add a word as to the importance, not to say necessity, to the engineer of a knowledge of the theory of combined internal stress, since all correct designing presupposes such knowledge.

STRESS ON A PLANE.—"If a body be conceived to be divided into two parts by an ideal plane traversing it in any direction, the force exerted between those two parts at the plane of division is *an internal stress*."—*Rankine.*

A STATE OF INTERNAL STRESS is such a state that an internal stress is or may be exerted upon every plane passing through a point at which such a state exists.

It is assumed as a physical axiom that the stress upon an ideal plane of division which traverses any given point of a body, cannot change suddenly, either as to direction or magnitude, while that plane is gradually turned in any way about the given point. It is also assumed as axiomatic that the stress at any point upon a moving plane of division which undergoes no sudden changes of motion, cannot change suddenly either as to direction of amount. A sudden variation can only take place at a surface where there is a change of material.

GENERAL PROPERTIES OF PLANE STRESS.

We shall call that stress *a plane stress* which is parallel to a plane; *e.g.*, let the plane of the paper be this plane and let the stress acting upon every ideal plane which is at right angles to the plane of the paper be parallel to the plane of the paper, then is such a stress a plane stress.

The *obliquity* of a stress is the angle included between the direction of the stress and a line perpendicular to the ideal plane it acts upon. This last plane we shall for brevity call the *plane of action* of the stress, and any line perpendicular to it, its *normal.* In plane stress, the planes of action are shown by their traces on the plane of the paper, and then their normals, as well as their directions, the magnitudes of the stresses, and their obliquities are correctly represented by lines in the plane of the paper.

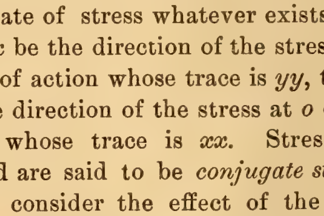
The definition of stress which has been given is equivalent to the statement that stress is *force* distributed over an area in such wise as to be in equilibrium.

In order to measure stress it is necessary to express its amount per unit of area: this is called the *intensity* of the stress.

Stress, like force, can be resolved into components. An oblique stress can be resolved into a component perpendicular to its plane of action called the *normal component,* and a component along the plane called the *tangential component* or *shear.*

When the obliquity is zero, the entire stress is normal stress, and may be either a compression or a tension, *i.e.*, a thrust or a pull. When the obliquity is $\pm 90°$, the stress consists entirely of a tangential stress or shear. If a compression be considered as a positive normal stress, it is possible to consider a normal tension as a stress whose obliquity is $\pm 180°$, and the obliquities of two shears having opposite signs, also differ by 180°.

Fig. 1



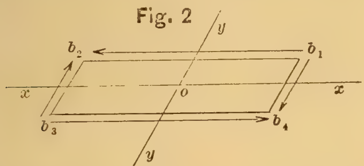
CONJUGATE STRESSES.—If in Fig. 1 any state of stress whatever exists at o, and xx be the direction of the stress on a plane of action whose trace is yy, then is yy the direction of the stress at o on the plane whose trace is xx. Stresses so related are said to be *conjugate stresses.*

For consider the effect of the stress upon a small prism of the body of which $a_1a_2a_3a_4$ is a right section. If the stress is uniform that acting upon a_1a_4 is equal and opposed to that acting upon a_2a_3, and therefore the stress upon these faces of the prism are a pair of forces in equilibrium. Again, the stresses upon

the four faces form a system of forces which are in equilibrium, because the prism is unmoved by the forces acting upon it. But when a system of forces in equilibrium is removed from a system in equilibrium, the remaining forces are in equilibrium. Therefore the removal of the pair of stresses in equilibrium acting upon a_1a_4 and a_2a_3 from the system of stresses acting upon the four faces, which are also in equilibrium, leaves the stresses upon a_1a_2 and a_3a_4 in equilibrium. But if the stress is uniform, the stresses on a_1a_2 and a_3a_4 must be parallel to yy, as otherwise a couple must result from these equal but not directly opposed stresses, which is inconsistent with equilibrium.

This proves the fact of conjugate stresses when the state of stress is uniform: in case it varies, the prism can be taken so small that the stress is sensibly uniform in the space occupied by it, and the proposition is true for varying stress in case the prism be indefinitely diminished, as may always be done.

Fig. 2



TANGENTIAL STRESSES.—If in Fig. 2 the stress at o on the plane xx is in the direction xx, *i.e.* the stress at o on xx consists of a shear only; then there necessarily exists some other plane through o, as yy, on which the stress consists of a shear only, and the shear upon each of the planes xx and yy is of the same intensity, but of opposite sign.

For let a plane which initially coincides with xx revolve continuously through 180° about o, until it again coincides with xx, the obliquity of the stress upon this revolving plane has changed gradually during the revolution through an angle of 360°, as we shall show.

Since the obliquity is the same in its final as in its initial position, the total change of obliquity during the revolution is 0° or some multiple of 360°. It cannot be 0°, for suppose the shear to be due to a couple of forces parallel to xx, having a positive moment; then if the plane be slightly revolved from its initial position in a plus direction, the stress upon it has a small normal component which would be of opposite sign if the pair of forces which cause it were reversed or changed in sign; or, what is equivalent to that, the sign of the small normal component would be reversed if the plane be slightly revolved from its initial position in a minus direction. Hence the plane xx, on which the stress is a shear alone, separates those planes through o on which the obliquity of the stress is greater than 90° from those on which it is less than 90°, *i.e.*, those having a plus normal component from those having a minus normal component.

Since in revolving through +180° the plane must coincide, before it reaches its final position, with a plane which has made a slight minus rotation, it is evident that the sign of the normal component changes at least once during a revolution of 180°. But a quantity can change sign only at zero or infinity, and since an infinite normal component is inadmissible, the normal component must vanish at least once during the proposed revolution. Hence the obliquity is changed by 360° or some multiple of 360° while the plane revolves 180°. In fact the normal component vanishes but once, and the obliquity changes by once 360° only, during the revolution.

It is not in every state of stress that there is a plane on which there is no stress except shear, but, as just shown, when there is one such plane xx there is necessarily another yy, and all planes through o and cutting the angles in which are b_1 and b_3 have normal components of opposite sign from planes through o and cutting the angles in which are b_2 and b_4.

To show that the intensity of the shear on xx is the same as that on yy, consider a prism one unit long and having the indefinitely small right section $b_1b_2b_3b_4$. Let the area of its upper or lower face be $a_1=b_1b_2$, that of its right or left face be $a_2=b_2b_3$, then a_1s_1 and a_2s_2 are the total stresses on these respective faces if s_1 and s_2 are the intensities of the respective shears per square unit. Let the angle $xoy=i$, then

$$a_1s_1 \,.\, a_2 \text{ sin. } i$$

is the moment of the stresses on the upper and lower faces of the prism, and

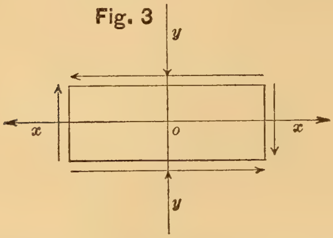
$$a_2 s_2 \cdot a_1 \sin. i$$

is the moment of the stresses on the right and left faces; but since the prism is unmoved these moments are equal.

$$\therefore s_1 = s_2$$

These stresses are at once seen to be of opposite sign.

Fig. 3



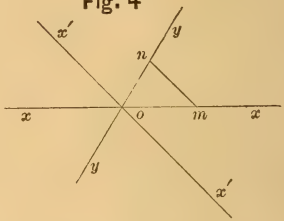
TANGENTIAL COMPONENTS.—In Fig. 3 if xx and yy are any two planes at right angles to each other, then the intensity at o of the tangential component of the stress upon the plane xx is necessarily the same as that upon the plane yy, but these components are of opposite sign.

For the normal components acting upon the opposite faces of a right prism are necessarily in equilibrium, and by a demonstration precisely like that just employed in connection with Fig. 2 it is seen that for equilibrium it is necessary and sufficient that the intensity of the tangential component on xx be numerically equal to that on yy, but of opposite sign.

STATE OF STRESS.—In a state of plane stress, the state at any point, as o, is completely defined, so that the intensity and obliquity of the stress on any plane traversing o can be determined, when the intensity and obliquity of the stress on any two given planes traversing that point are known.

For suppose in Fig. 4 that the intensity and obliquity of the stress on the given planes xx and yy are known, to find that on any plane $x'x'$ draw $mn \parallel x'x'$ then the indefinitely small prism one unit in length whose right section is mno, is held in equilibrium by the forces acting upon its three faces. The forces acting upon the faces om and on are known in direction from the obliquities of the stresses, and, if p_x and p_y are the respective intensities of the known stresses, then the forces are $om.p_x$ and $on.p_y$ respectively. The resultant of these forces and the reaction which holds it in equilibrium, together constitute the stress acting on the face mn: this resultant divided by mn is the intensity of the stress on mn and its direction is that of the stress on mn or $x'x'$.

Fig. 4



It should be noticed that the stress at o on two planes as xx and yy cannot be assumed at random, for such assumption would in general be inconsistent with the properties which we have shown every state of stress to possess. For instance we are not at liberty to assume the obliquities and intensities of the stresses on xx and yy such that when we compute these quantities for any plane $x'x'$ and another plane $y'y'$ at right angles to $x'x'$ in the manner just indicated, it shall then appear that the tangential components are of unequal intensity or of the same sign. Or, again, we are not at liberty to so assume these stresses as to violate the principle of conjugate stresses.

But in case the stresses assumed are conjugate, or consist of a pair of shears of equal intensity and different sign on any pair of planes, or in case any stresses are assumed on a pair of planes at right angles such that their tangential components are of equal intensity but different sign, we know that we have made a consistent assumption and the state of stress is possible and completely defined.

The state of stress is not completely defined when the stress upon a single plane is known, because there may be any amount of simple tension or compression along that plane added to the state of stress without changing either the intensity or obliquity of the stress on that plane.

Principal Stresses.—In any state of stress there is one pair of conjugate stresses at right angles to each other, *i.e.* there are two planes at right angles on which the stresses are normal only. Stresses so related are said to be *principal stresses.*

It has been previously shown that if a plane be taken in any direction, and the direction of the stress acting on it be found, then these are the directions of a pair of conjugate stresses of which either may be taken as the plane of action and the other as the direction of the stress acting upon it.

Consider first the case in which the state of stress is defined by a pair of conjugate stresses of the same sign; *i.e.*, the normal components of this pair of conjugate stresses are both compressions or both tensions.

It is seen that they are of opposite obliquities, and if a plane which initially coincides with one of these conjugate planes of action be continuously revolved until it finally coincides with the other, the obliquity must pass through all intermediate values, one of which is 0°, and when the obliquity is 0° the tangential component of the stress vanishes. But as has been previously shown there is another plane at right angles to this which has the same tangential component; hence the stress is normal on this plane also.

Consider next the case in which the pair of conjugate stresses which define the state of stress are of opposite sign, *i.e.*, the normal component on one plane is a compression and that on the other a tension.

In this case there is a plane in some intermediate position on which the stress is tangential only, for the normal component cannot change sign except at zero. It has been previously shown that in case there is one plane on which the stress is a shear only, there is another plane also on which the stress is a shear only, and that this second shear is of equal intensity with the first but of opposite sign. Let us consider then that the state of stress, in the case we are now treating, is defined by these opposite shears instead of the conjugate stresses at first considered.

Now let a plane which initially coincides with one of the planes of equal shear revolve continuously until it finally coincides with the other. The obliquity gradually changes from $+90°$ to $-90°$, during the revolution, hence at some intermediate point the obliquity is 0°; and since the tangential component has the same intensity on a plane at right angles to this, that is another plane on which the obliquity of the stress is also 0°.

We have now completely established the proposition respecting the existence of principal stresses which may be restated thus:

Any possible state of stress can be completely defined by a pair of normal stresses on two planes at right angles to each other.

As to the direction of these principal planes and stresses, it is easily seen from considerations of symmetry that in case the state of stress can be defined by equal and opposite shears on a pair of planes, that the principal planes bisect the angles between the planes of equal shear, for there is no reason why they should incline more to one than to the other. We have before shown that the planes of equal shear are planes of separation between those whose stresses have normal components of opposite sign: hence it appears that the principal stresses are of opposite sign in any state of stress which can be defined by a pair of equal and opposite shears on two planes.

It will be hereafter shown how the direction and magnitude of the principal stresses are related to any pair of conjugate stresses.

For convenience of notation in discussing plane stress let us denote *compression* by the sign +, and *tension* by the sign −.

Let us also call that state of stress which is defined by equal principal stresses of the same sign *a fluid stress.* A material fluid can actually sustain only a + fluid stress, but it is convenient to include both compression and tension under one head as fluid stress, the properties of which we shall soon discuss.

Let us call a state of stress which is defined by unequal principal stresses of the same sign *an oblique stress.* This

may be taken to include fluid stress as the particular case in which the inequality is infinitesimal. In this state of stress there is no plane on which the stress is a shear only, and the normal component of the stress on any plane whatever has the same sign as that of the principal stresses.

Furthermore let us call that state of stress which is defined by a pair of shearing stresses of equal intensity and different sign on two planes at right angles to each other *a right shearing stress.* We shall have occasion immediately to discuss the properties of this kind of stress, but we may advantageously notice one of its properties in this connection. It has been seen previously from considerations of symmetry that the principal stresses and planes which may be used to define this state of stress, bisect the angles between the planes of equal shear. Hence in right shearing stress the principal stresses make angles of 45° with the planes of equal shear. We can advance one step further by considering the symmetrical position of the planes of equal shear with respect to the principal stresses and show that the principal stresses in a state of right shearing stress are equal but of opposite sign.

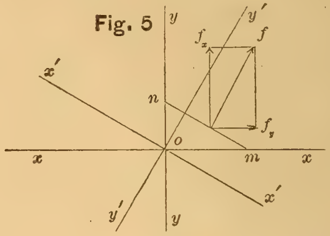
We wish to call particular attention to fluid stress and to right shearing stress, as with them our subsequent discussions are to be chiefly concerned: they are the special cases in which the principal stresses are of equal intensities, in one case of the same sign, in the other case of different sign.

Let us call a state of stress which is defined by a pair of equal shearing stresses of opposite sign on planes not at right angles *an oblique shearing stress.* The principal stresses, which in this case are of unequal intensity and bisect the angles between the planes of equal shear, are of opposite sign. A right shearing stress may be taken as the particular case of oblique shearing in which the obliquity is infinitesimal.

We may denote a state of stress as + or — according to the sign of its larger principal stress.

Fluid Stress.—In Fig. 5 let xx and yy be two planes at right angles, on which the stress at o is normal, of equal intensity and of the same sign; then the stress on any plane, as $x'x'$, traversing o is normal, of the same intensity and same sign as that on xx or yy.

Fig. 5



For consider a prism a unit long and of infinitesimal cross section having the face $mn \parallel x'x'$, then the forces f_x and f_y, acting on the faces om and on are such that

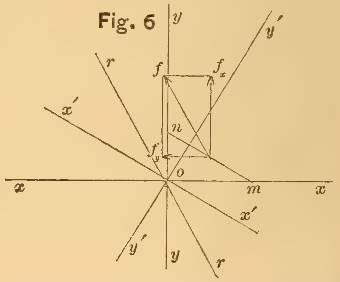
$$f_x : f_y :: om : on.$$

Now $nm = \sqrt{om^2 + on^2}$, and the resultant force which the prism exerts against nm is

$$f = \sqrt{f_x^2 + f_y^2}, \quad \therefore f_x : f :: om : mn.$$

But $f_x \div om$ is the intensity of the stress on xx and $f \div mn$ is the intensity of the stress on $x'x'$, and these are equal. Also by similarity of triangles the resultant f is perpendicular to mn.

Fig. 6



Right Shearing Stress.—In Fig. 6, let xx and yy be two planes at right angles to each other, on which the stress is normal, of equal intensity, but of opposite sign; then the stress on any plane, as $x'x'$, traversing o is of the same intensity as that on xx and yy, but its obliquity is such that xx and yy respectively, bisect the angles between the direction rr of the resultant stress, and the plane of action $x'x'$ and its normal $y'y'$.

For, if the intensity of the stress on $x'x'$ be computed in the same manner as in Fig. 5, the intensity is found to be the same as that on xx or yy; for the stresses to be combined are at right angles and are both of the same magnitude. The only difference between this case and that in Fig. 5 is this, that one of the component stresses, that one normal to yy say, has its sign the opposite of that in Fig. 5. In Fig. 5 the stress on $x'x'$ was in the direction $y'y'$, making a certain angle yoy' with yy. In Fig. 6 the resultant stress on $x'x'$ must then make an equal negative angle with yy, so that $yor = yoy'$. Hence the statement which has been made respecting right shearing stress is seen to be thus established.

COMBINATION AND SEPARATION.—Any states of stress which coexist at the same point and have their principal stresses in the same directions xx and yy combine to form a single state of stress whose principal stresses are the sums of the respective principal stresses lying in the same directions xx and yy: and conversely any state of stress can be separated into several coexistent stresses by separating each of its two principal stresses into the same number of parts in any manner, and then grouping these parts as pairs of principal stresses in any manner whatever.

The truth of this statement is necessarily involved in the fact that stresses are forces distributed over areas, and that as a state of stress is only the grouping together of two necessarily related stresses, they must then necessarily follow the laws of the composition and resolution of forces.

For the sake of brevity, we shall use the following nomenclature of which the meaning will appear without further explanation.

The terms applied to forces and stresses are:	The terms applied to states of stress are:
Compound,	*Combine,*
Composition,	*Combination,*
Component,	*Component state,*
Resolve,	*Separate,*
Resolution,	*Separation,*
Resultant.	*Resultant state.*

Other states of stress can be combined besides those whose principal stresses coincide in direction, but the law of combination is less simple than that of the composition of forces; such combinations will be treated subsequently.

COMPONENT STRESSES.—Any possible state of stress defined by principal stresses whose intensities are p_x and p_y on the planes xx and yy respectively is equivalent to a combination of the fluid stress whose intensity is $+\frac{1}{2}(p_x + p_y)$ on each of the planes xx and yy respectively, and the right shearing stress whose intensity is $+\frac{1}{2}(p_x - p_y)$ on xx and $-\frac{1}{2}(p_x - p_y)$ on yy.

For as has been shown, the resultant stress due to combining the fluid stress with the right shearing stress is found by compounding their principal stresses. Now the stress on xx is

$$\tfrac{1}{2}(p_x + p\ ) + \tfrac{1}{2}(r_x - p_y) = p_x$$

and that on yy is

$$\tfrac{1}{2}(p_x + p_y) - \tfrac{1}{2}(p_x - p_y) = p_y$$

and hence these systems of principal stresses are mutually equivalent

In case $p_y = 0$, the stress is completely defined by the single principal stress p_x, which is a simple normal compression or tension on xx. Such a stress has been called a *simple stress.*

A fluid stress and a right shearing stress which have equal intensities combine to form a simple stress.

It is seen that the definition of a state of stress by its principal stresses, is a definition of it as a combination of two simple stresses which are perpendicular to each other.

There are many other ways in which any state of stress can be separated into component stresses, though the separation into a fluid stress and a right shearing stress has thus far proved more useful than any other, hence most of our graphical treatment will depend upon it. It may be noticed as an instance of a different separation, that it was shown that the tangential components of the stresses on any pair of planes xx and yy at right angles to each other are of equal intensity but opposite sign. These tangential components, then, together form a right shearing stress whose prin-

cipal planes and stresses $x'x'$ and $y'y'$ bisect the angles between xx and yy, while the normal components together define a state of stress whose principal stresses are, in general, of unequal intensity.

Hence any state of stress can be separated into component stresses one of which is a right shearing stress on any two planes at right angles and a stress having those planes for its principal planes.

The fact of the existence of conjugate stresses points to still another kind of separation into component stresses.

THE MODULUS OF ELASTICITY IN SOME AMERICAN WOODS, AS DETERMINED BY VIBRATION.

By Dr. MAGNUS C. IHLSENG.

Written for Van Nostrand's Magazine.

The importance of this factor, so necessary for construction, is sufficiently acknowledged to warrant the use or arrangement of new methods for its accurate determination. The various direct methods which are now employed are more or less elaborate, involving a large outlay in apparatus. We have, however, a more ready means for ascertaining this value, one which is not usually resorted to, namely, by vibration.

When any rod or solid body is rubbed by a resined woolen cloth in the direction of its axis, it is urged into longitudinal vibration and gives out a note of high pitch. The particles of the rod are excited by a force which acts along the direction of the fibres and they will move backward and forward, thus executing an oscillation. This vibratory movement of the particles produces a pulse running through the entire length of the rod in a given time, and this motion continues while the exciting cause is acting, the velocity depending upon the structure of the material. The propagation of this vibration, however, depends upon the elastic force of the molecules and not on the tension which is applied externally. The more elastic the body is the greater will be the rapidity of transmission. So, it is evident, that the rapidity of vibration, or, in other words, the pitch of the note which the rod is sounding, depends upon the velocity with which this pulse is propagated. If, now, we ascertain the pitch of the note, by counting the number of vibrations per second, we have determined the velocity of propagation by substitution in this simple formula:

$$v=2\ n.l,$$

in which v is the velocity per second, and n the number of vibrations executed by the rod, whose length is l. The length may be two meters, the thickness about 20 mm. The specimen should be, of course, as free as possible from imperfections.

To measure the rate of vibration of the rod, I employed a simple direct process, which has been fully detailed, having been read before the National Academy of Sciences, Oct., 1877.

In brief, the *modus operandi* is this; the rod to be experimented upon is clamped in the center by a vise, one end being free, the other end having a small brass pen fastened to it. This brass pen is bent somewhat and rests upon a smoked glass plate. When the rod is set into vibration by rubbing it along the free end, by a resined woolen cloth, the glass plate is moved under the pen by means of a falling weight. A tuning fork of a known rate simultaneously registers its vibration on the plate; the two pens have now described two traces, the number of vibrations in each depending on the ratio between the two notes of the rod and fork. Two parallel lines are drawn upon the plate, embracing a given period of time. The number of the waves in each of the two traces are then counted between these parallel lines, by means of a low power microscope.

In this manner, the rates of vibration of several rods were determined. By calculation, v was obtained, which by substitution in the following formula, gives us the the value for the coefficient of elasticity;

$$\varepsilon = \frac{(39.37041 \times v)^2}{g} \times m.$$

v=the velocity of sound in meters as calculated above; g is the accelerating force of gravity; m is the weight of one cubic inch of the substance, in pounds; the factor, 39.37041 is the number of inches in a meter.

The following table shows the results of the experiments upon the several varieties of wood. The degree of humidity of these specimens was not found as they were well seasoned and in the condition employed in commerce. The determinations are all average values of from ten to fifteen observations:

	Specific Gravity.	Length.	Number of Vibrations.	Velocity per Second.	Modulus of Elasticity. inch lbs.
Cypress	.432	1.836 M	1033.53	3797.2 M	901020
"	.482	1.8384	1107.97	4073.89	1157100
"	.465	1.83875	1050.93	3864.79	1004700
"	.417	1.83672	1132.8	4161.65	1044700
"	.478	1.650	1187.3	3918.14	1061500
Poplar	.476	1.83857	1339.98	4927.4	1710700
"	.443	1.834	1418.	5201.2	1733560
"	.425	1.21236	2041.8	4950.68	1506800
"	.478	1.114237	2035.47	4650.4	1496880
Shell bark Hickory	.922	1.5505	——	4110.1	2253000
White Pine	.491	1.8419	1279.5	4713.4	1577890
White Pine	.432	1.8426	1227.21	4522.47	1278100
White Ash	.544	1.8365	1165.94	4282.44	1443140
White Ash	.541	1.83826	1159.13	4261.51	1421100
White Holly	.562	1.3785	1326.58	3657.4	1087450
Mahogany	.540	1.3491	1532.6	4135.3	1335800
Black Walnut	.518	1.37863	1734.1	4780.7	1712500
Wild Cherry	.693	1.5601	1413 26	4409.5	1949160
Yellow Pine	.664	1.0524	2030.83	4274.5	1754940
Red Oak	.650	1.4947	1395.04	4179.8	1644160
White Oak	.775	1.4945	1443.93	4316.5	2090050

There have been few experiments upon the elasticity of woods by any similar methods of vibration. Wertheim,* who alone has any extended investigations upon this point, decides that the coefficient obtained by vibration is greater than that from elongation, by about a per cent. This he explained by assuming a slight increase of temperature as produced by the compression of the particles of the rod. More recent modifications, however, show that the heat disengaged in the transmission of this motion has little influence.

The advantages of the present method are evident, as the number of vibrations are directly registered, a process, which Weisbach, by the bye, considered impracticable.† I have also shown in my article, above alluded to, that this method gives results which are lower than those obtained from Kundt's air method, by one per cent. or more; thus, perhaps, bringing it nearer the truth. Moreover, the rod registers the same number of vibrations, within the limits of error, that is given by a standard tuning fork to which the rod has been brought into unison.

* *Annalen der Chemie et Physique*, Ser. III, T. 12, p. 385, and *Comptes rendus*, Tome 23, p. 663.

† Weisbach, Mechanics' of Engineering, Coxe, Vol. I, p. 1077.

THE Don Pedro Segundo Railway line has reached its highest point, an altitude of 3550 ft., 225 miles from Rio de Janeiro, in traversing the gorge of Juan Ayres, in the Mantiqueira range, whose highest peak is Itatiaia, 8380 ft. in altitude. The Pyrenees range, in Goyaz, although not so towering in outline as the Mantiqueira range, has been found to be over 1000 ft. higher, and to be the highest in Brazil—its real backbone, in fact.

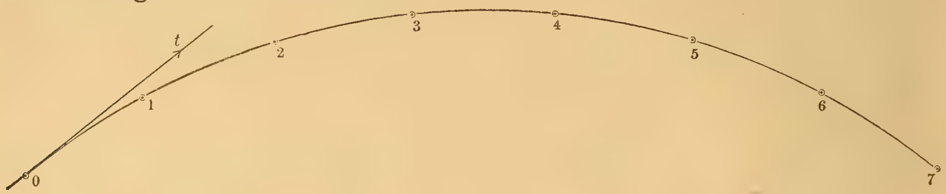
CIRCULAR CURVES FOR RAILWAYS.

By Prof. WM. M. THORNTON, University of Virginia.

Written for Van Nostrand's Magazine.

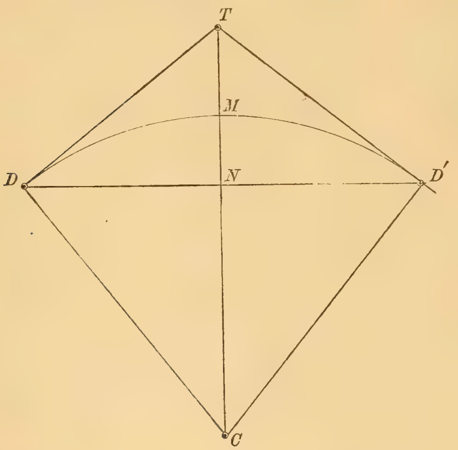
§ 1. SIMPLE CURVES.

1. Setting out a circular curve:



The deflection angle of a circular curve is the angle subtended at any point of it by a chord one chain long. If this angle d be given and the tangent at the origin o, it is easy to set out such a curve. Plant the transit at o, set the vernier at zero, sight to t and clamp the lower motion. Release the upper motion, deflect d to 01 and make 01 equal to one chain. Deflect d again to 02 and make 12 equal to one chain; and so on.

2. Elements of the curve:



The elements of such a curve are

d, the deflection angle,
r radius,
s semichord,
t tangent,
D total deflection.

Thus in the diagram CD=CD′=r, DD′=2s, DN=S, DT=D′T=t, TDD′ =TD′D=D. All lengths are in chains of 100 links, all angles in minutes.

3. Fundamental formulæ:

It is obvious geometrically that DCT =D. Whence the following formulæ

$$\sin. D=\frac{s}{r},$$

$$\tan. D=\frac{t}{r},$$

$$\sin. d=\frac{1}{2r};$$

the last formula is a special case of the first. For when D=d, 2s=1. These formulæ are exact and afford the solution of all possible cases. In applying them to numerical examples it is most convenient to throw them first into the logarithmic form, thus:

$$Lr=\bar{1}.69897-L\sin. d,$$
$$Ls=Lr+L\sin. D,$$
$$Lt=Lr+L\tan. D.$$

The following example shows the most convenient order for conducting the computation:

$$d=73', D=24° 19'$$

	$\bar{1}$.69897		
L sin. d	8.32702		
Lr	$\bar{1}$.37195	r	23.55
L sin. D	9.61466		
L tan. D	9.65501		
Ls	0.98661	s	9.70
Lt	1.02690	t	10.64

The computations are sufficiently simple. But as it would be necessary for the engineer to carry into the field a set of logarithmic tables and to interrupt his work to perform the computations, the approximate formulæ in the following article have been devised. These

reduce the necessary computations to a few easy divisions, by means of a small collection of tables.

4. Approximate formulæ:

If x be expressed in circular measure

$$\sin. x = x - \frac{x^3}{6} + \frac{x^5}{120} \quad . \quad . \quad . \quad ,$$

$$\therefore \; x - \sin. x < \frac{x^3}{6}$$

Remembering then that d is expressed in minutes and that $\sin. d = \frac{1}{2r}$, we have

$$d - \frac{5400}{\pi r} < \frac{\pi^2 d^3}{6.10800^2}$$

The second member is less than $\frac{1}{2}$ if $d < 521$; that is if $r > 3.30$. No greater curvature than this should be permitted in railway curves. Accordingly the formula

$$d = \frac{5400}{\pi r}$$

gives the value of d for a given r within a half minute in defect. It is therefore for railway practice as good as exact. Hence if we put

$$m = \frac{5400}{\pi} = 1718.87;$$

$$S = m \sin. D,$$

$$T = m \tan. D,$$

we have the formulæ

$$dr = m, \; ds = S, \; dt = T$$

5. Tables:

The tables required for use with this method are a table for r with d as argument, and tables for S T, with D as argument. Such tables arranged in a convenient form are appended to this article.

6. Short chords:

At the terminus of a curve it is frequently necessary to use a short chord to join it to the tangent. A short chord is also frequently used to complete a chain begun on the initial tangent. In either case the appropriate deflection angle is easily found. For if d_x be the required angle, c_x the length of the chord then

$$\sin. d_x = \frac{c_x}{2r}$$

But since d_x is less than d we can put

$$\sin. d_x = \frac{d_x}{2m}$$

$$\therefore \; d_x = dc_x$$

7. Length of the curve:

The number of chords in the curve is obviously given by the formula

$$nd = D$$

The fractional part of n if any will by the last article be the length of the short chord necessary to complete the curve. Thus in the example treated in (1, 3)

$$n = \frac{24°19'}{73'} = 19.99:$$

so that the curve consists practically of 20 chains. If $d = 112'$, $D = 31° \; 12'$

$$n = 16.71$$

so that the curve consists of 16 chains and a short chord of 71 links, the deflection angle for which is

$$d_x = 112' \times 0.71 = 80'$$

8. Long chords:

Chords running two or more stations are often used to test the accuracy of the field work. If x be the number of stations, c_x the length of the chord

$$c_x = 2r \sin. dx,$$

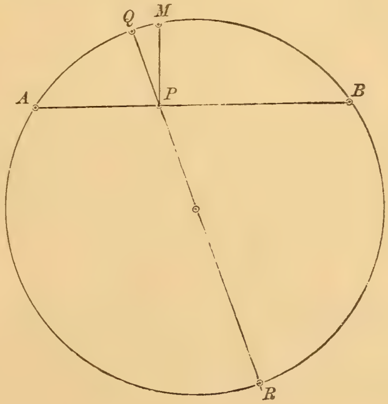
But $$\sin. dx = \frac{S_{dx}}{m},$$

$$\therefore \; dc_x = 2S_{dx}.$$

S_{dx} is taken from the S—Table and c_x found by an easy division:

9. Ordinates:

Intermediate points on the curve are fixed by means of ordinates or offsets normal to the chord.



If AB be the chord, PAI the normal to the chord, IQ the normal to the curve we may disregard the difference between PM, IQ and put PQ$=y$ the required ordinate. If therefore PA$=x$

$$y(2r-y)=x(1-x);$$

or since y is very small in comparison with r

$$y=\frac{x(1-x)}{2r}$$

For the middle ordinate $x=\frac{1}{2}$ and hence

$$y_0=\frac{1}{8r}$$

For the quarter ordinates $x=\frac{1}{4}$ and hence $y_1=\frac{3}{4}\ y_0$. In terms of the deflection angle we have

$$y_0=0.00007274\ d.$$

* For bending rails of length l the analogous formula is

$$y_0=0.00007274\ dl^2.$$

10 Cant:

The centrifugal force acting on a mass m revolving in a circle of radius r feet, with velocity v feet per second is $\frac{mv^2}{r}$; the weight of the same mass is mg. The resultant of these forces must be normal to the road bed. Hence if G be the gauge, H the cant or superelevation of the outer rail both expressed in the same unit

$$\frac{H}{G}=\frac{v^2}{gr}.$$

In practice the velocity is usually given in miles per hour V; and hence

$$3600\ v=5280\ V,$$

$$dr=171887;$$

$$g=32.1695;$$

$$\therefore\ \frac{H}{G}=qdV^3$$

where q is a constant factor such that

$$Lq=\bar{7}.58999$$

For the ordinary gauge 4′ 8½″ we have for the cant in inches

$$H=0.00002198\ dV^2.$$

* Reducing the coefficient to a continued fraction and calculating the convergents we find for the middle ordinate in links the practically exact and very simple formula $\frac{8}{11}\cdot\frac{d}{100}$. The side ordinates will be $\frac{6}{11}\cdot\frac{d}{100}$. The formulæ are so simple that no table is needed.

or with a high degree of accuracy

$$\frac{H}{d}=\frac{22V^2}{10^6}$$

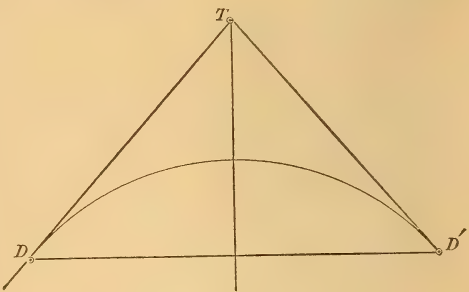
The following table gives the values of $1000\ \frac{H}{d}$ for equidistant values of V.

15	20	25	30	35	40	45	50
5	9	14	20	27	35	45	55

11. Field Problems:

The problems which arise in the field have been exhaustively treated by so many writers that it will be necessary simply to indicate the mode in which our formulæ and tables are applied. The data are as follow:

A. The origin, the tangent there and the terminus.



Measure DD′$=2$S, TDD′$=$D. Then take S from the table. We shall then have

$$d=\frac{S}{s},\ n=\frac{D}{d}$$

and the curve is set out as in (1, 1)

B. The origin, the terminus and the curvature.

Measure DD′ $=$ 2S. Then S $=ds$; whence D from the S table. Set out D′DT$=$D and proced as in (1, 1)

C. The origin and both tangents.

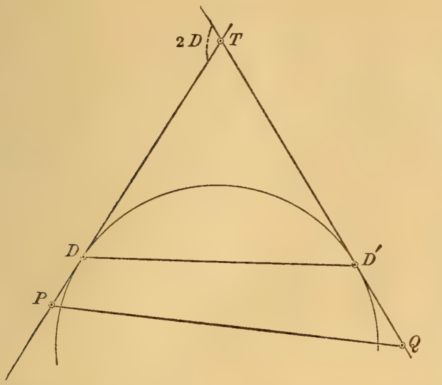
1. Point of concourse of the tangents accessible:

Plant the transit at T and measure the exterior angle which is 2D; measure also the tangent TD$=t$. Then having got T from the table we have

$$d=\frac{T}{t},\ n=\frac{D}{d}$$

2. Point of concourse of the tangents inaccesssible

Set out and measure PQ and the



angles P, Q. Or where this is impossible determine the *nv* by a traverse. Then

$$2D=P+Q,$$

$$PT=PQ\,\frac{\sin.\ Q}{\sin\ 2D},=PQ.\,\frac{S_Q}{S_{2D}}$$

$$t=PT-PD.$$

D. The curvature and both tangents:

1. Point of concourse accessible:

Measure the exterior angle T=2D, and take T from the table. Then

$$t=\frac{T}{d},\ n=\frac{D}{d}.$$

The first formula fixes D, the origin.

2. Point of concourse inaccessible:

Set out and measure PQ and the angles P, Q. Then

$$2D=F+Q,$$

$$PT=PQ.\frac{\sin.\ Q}{\sin.\ 2D}=PQ.\frac{S_Q}{S_{2D}},$$

$$t=\frac{T}{d},$$

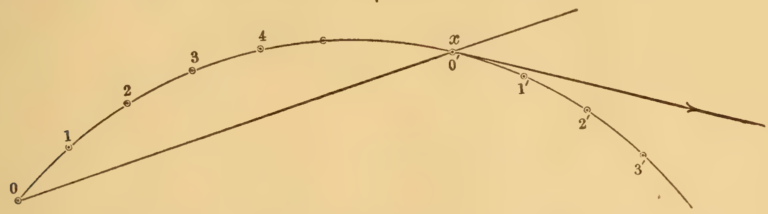
$$n=\frac{D}{d},$$

$$PD=PT-t.$$

The last formula fixes the origin.

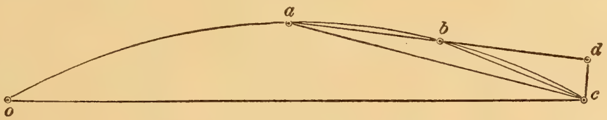
12. Obstacles:

A. When the stations after x are no longer visible from 0.



The telescope being set on x clamp the vernier plate, remove the transit and plant at x. Sight back to o by the lower motion and clamp. Reverse the telescope and release the vernier plate. Bring the vernier back to zero and continue setting out as from a new origin o'.

B. When two stations b, c are visible from the origin o but the chord between them bc cannot be measured.



To fix c

(1) Measure the long chord oc.

(2) Measure the chord from the second station back, ac.

(3) Range out $bd=ab$, and make $dc=\frac{1.}{r}$

13. Corrections:

Having run a curve from a given tangent terminating in a certain tangent, it is required to determine a curve which will terminate in a parallel tangent.

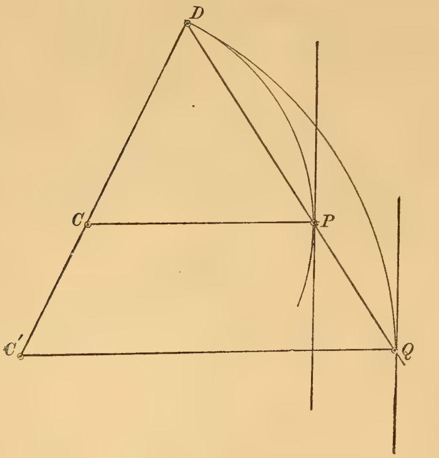
(1) Without changing the origin.

Since the deflection remains the same the new terminus Q will lie in the prolongation of DP where it cuts the parallel tangent. Fix Q and measure PQ. Then if $s'=s+PQ$

$$d'=\frac{S}{s'},$$

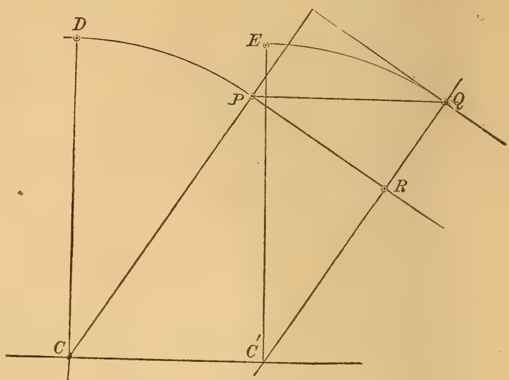
(2) Without changing the curvature:

Set out PP parallel to the initial tangent, measure PQ and make DE=PQ.

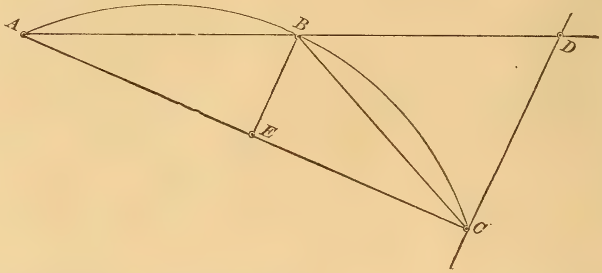


Or measure the horizontal distance QR $=h$ between the tangents and make

$$\mathrm{DE}=\frac{hcsc}{\mathrm{S}_{2\mathrm{D}}}2\mathrm{D}.$$



14. To find the curvature of a given curve:



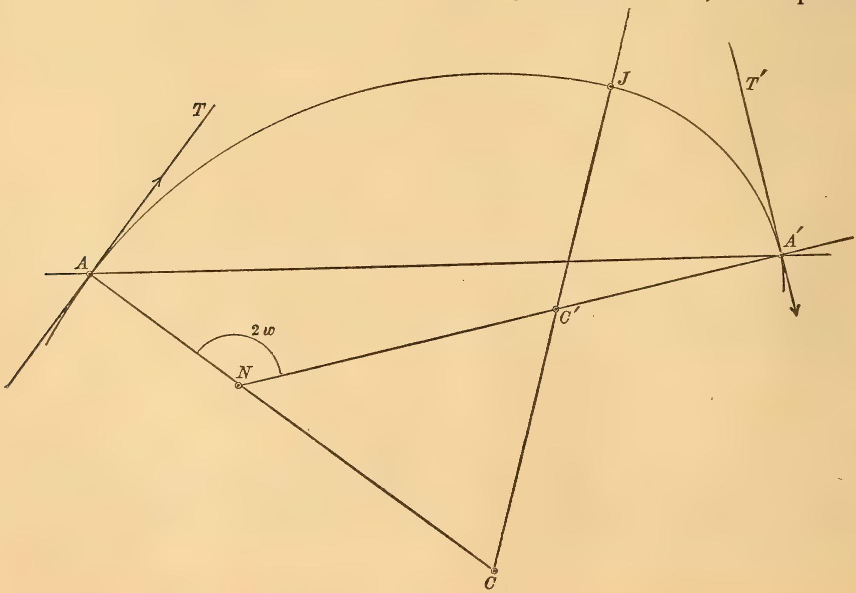
Make AB=BC=ED=1 ch. and AE perpendicular to AC. Then

$$d=\mathrm{CAD}=\tfrac{1}{2}\ \mathrm{CBD},$$

$$r=\frac{1}{\mathrm{CD}}=\frac{1}{2\mathrm{BE}}$$

§ 2. COMPOUND CURVES.

1. When the tangents are on opposite sides of the chord which joins the terminal points of a railway curve and are equally inclined to it, a simple curve



consisting of a single circular arc may be used to unite them. But when the angles of inclination are unequal a compound curve, consisting of two circular arcs with their curvatures, in the same direction and tangent to each other at their point of juncture must be used to write them.

2. Formulæ:

Let A, A' denote the angles of inclination of the tangents to the chord.

2ω denote the exterior angle between them.

n, n' denote the length of the normals.

D, D' denote the deflections of the arcs.

r, r' denote the radii.

d, d' denote the deflection angles.

$2c$ denote the lengths of the chord.

Then it is obvious that

(1) $$2\omega = A + A' = 2D + 2D',$$

$$(r-r')^2 = (r-n)^2 + (r'-n')^2 + 2(r-n)(r'-n') \cos. 2\omega,$$

which is reducible to the form

(2) $$r \sin. A + r' \sin. A' = \frac{rr'}{c} \cos.^2\omega + c$$

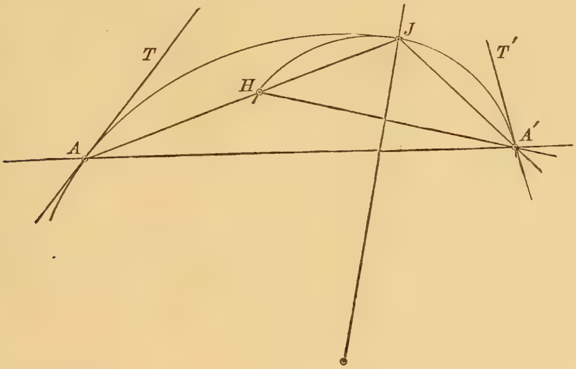
or (2′)

$$d \sin. A' + d' \sin. A = \frac{m}{c} \cos.^2\omega + \frac{c}{m} dd',$$

or (2″)

$$d = \frac{m}{c} \sin. A \frac{1 - \frac{r'}{c} \frac{\cos.^2\omega}{\sin. A}}{1 - \frac{r'}{c} \sin. A'}$$

3. Solutions:



A. One radius assumed:

1. Set out $A'H$ so that $HA'T' = \omega$ and $A'H = \frac{2S\omega}{d'}$. Then measure $HAT = D$ and set out $A'J$ to meet AJ in J making $HA'J = D$. Then set out the curves $AJ, A'J$ by the rules of § 1.

2. Having assumed r' computed by equation (2″) above and set out the two branches of the curve as in § 1.

B. One deflection assumed.

1. Having assumed D we have $D' = \omega - D$. Set out AJ, $A'J$ to meet in J, making $TAJ = D$, $T'A'J' = D'$ and then set out the curves AJ, $A'J$ by the rules of § 1.

2. Having assumed D and found D' we compute the other elements of the arcs by the following formulæ

$$s = \frac{c}{\sin. \omega} \sin.(A' - D'),$$

$$s' = \frac{c}{\sin. \omega} \sin. (A - D),$$

$$d = \frac{S}{s}, \quad d' = \frac{S'}{s'},$$

$$n = \frac{D}{d}. \quad n' = \frac{D'}{d'}.$$

It would be easy to show by means of equation (2) that the best conditions of curvature are obtained by making the common normal JCC' perpendicular to the common chord AA'. That is, by making $2D = A$, $2D' = A'$. It is altogether possible, however, that the construction of the curve thus obtained may be attended with disadvantages which more than compensate its benefits.

§ 3. REVERSE CURVES.

1. When the tangents are on the same side of the chord which joins the termini neither a simple curve nor a compound curve can be used. We must have recourse to a curve composed of two circular arcs tangent to each other at their junction with their curvatures in opposite directions.

2. Formulæ:

Let A,A′ denote the angles of inclination of the tangents to the chord.

2ω denote the interior angle between them.

n,n' denote the lengths of the normals.

D,D′ denote the deflections of the arcs.

r,r' denote the radii,

d,d' denote the deflection angles.

$2c$ denote the length of the chord.

Then it is obvious that

(1) $$2\omega = \text{A} - \text{A}' = 2\text{D} - 2\text{D}',$$

$$(r+r')^2 = (n-r)^2 + (n'+r')^2 - 2(n-r)(n'+r')\cos.\ 2\omega$$

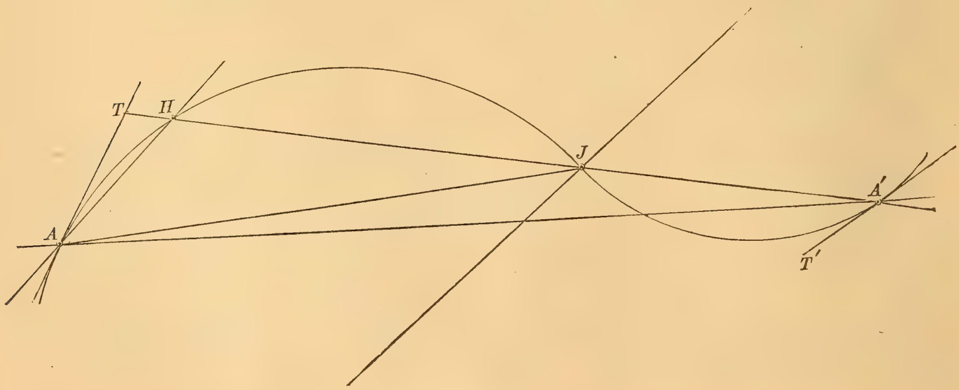
which is reducible to the form

(2) $$r\sin.\ \text{A} + r'\sin.\ \text{A}' = c - \frac{rr'}{c}\sin.^2\omega$$

or (2′)

$$d = \frac{m}{c}\sin.\ \text{A}.\ \frac{1+\dfrac{r'}{c}.\dfrac{\sin.^2\omega}{\sin.\ \text{A}}}{1-\dfrac{r'}{c}\sin.\ \text{A}'}$$

3. Solutions:



A. One radius assumed:

1. Set out AH so that HAT$=\omega$, AH $=\frac{2S\omega}{d}$ and measure HA′T′=D′. Then set out AJ to meet A′H in J so that HAJ=D′. Then the curves AJ, A′J may be set out by the rules of § 1.

2. Having assumed r' compute d by equation 2′) above, and then set out the two branches of the curve as in § 1.

B. One deflection assumed:

1. Having assumed D we have D′=D $-\omega$. Set out AJ, A′J to meet in J, so that TAJ=D, T′A′J=D′ and then set out the curves AJ, A′J by the rules of § 1.

2. Having assumed D and found D′ compute the other elements of the arcs by the following formulæ:

$$s=\frac{c}{\sin.\ \omega}.\ \sin.\ (\mathrm{A}'+\mathrm{D}'),$$

$$s'=\frac{c}{\sin.\ \omega}\ \sin.\ (\mathrm{D}+\mathrm{A}),$$

$$d=\frac{\mathrm{S}}{s},\quad d'=\frac{\mathrm{S}'}{s'},$$

$$n=\frac{\mathrm{D}}{d};\quad n'=\frac{\mathrm{D}'}{d'}.$$

4. Special case:

When the tangents are parallel $\omega=o$; whence J lies in AA′ and D=D′=A. The relation between the radii becomes

$$r+r'=\frac{c}{\sin.\ \mathrm{A}}.$$

Unless some specific reason forbids it is best to make $r=r'$; hence

$$d=d'=\frac{2\mathrm{S}_{\mathrm{A}}}{c}$$

$$n=n'=\frac{\mathrm{D}}{d}$$

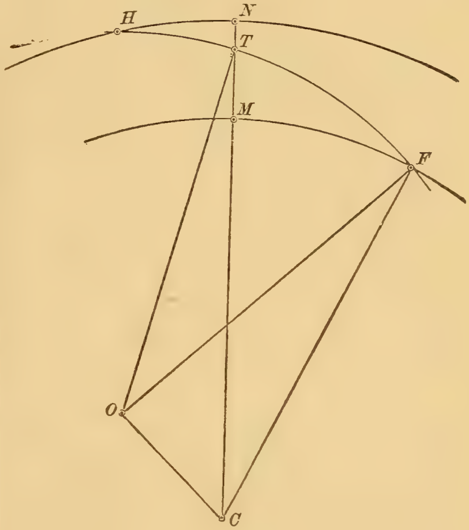
remembering that D=A

§ 4. SWITCHES AND FROGS.

1. The data in setting a frog are the length and travel of the switch and the number of the frog. The circular measure of the switch angle is the quotient of the travel by the length. The circular measure of the frog angle is the reciprocal of its trade number.

2. Setting the frog:

In the diagram H is the heel of the switch, T the toe, F the point of the frog, TN the travel, c the center of the main line, o the center of the turn out. OTC is therefore the switch angle, OFC the frog angle.



Let G denote the gauge.

- J denote the travel.
- p denote the circular measure of the switch angle.
- q denote the circular measure of the frog angle.
- r denote the radius of the main line.
- ρ denote the radius of the outer rail of the turn out.
- d denote the deflection angle of the main line.
- δ denote the deflection angle of the outer rail of the turn out.

If a,b be two sides of a triangle including the very small angle x and c the third side, then very nearly

$$c^2=(a-b)^2+abx^2.$$

Apply this formula to the triangles TOC, FOC. We have for OC² the equivalent expressions

$$(\mathrm{CT}-\mathrm{OT})^2+\mathrm{OT.CT}.p^2 =(\mathrm{CF}-\mathrm{OF})^2+\mathrm{OF.CF}.q^2,$$

$$\therefore\ (\mathrm{CT}-\mathrm{CF})(\mathrm{CT}+\mathrm{CF}-2\mathrm{OT}) =\mathrm{OT}(\mathrm{CF}.q^2-\mathrm{CT}.p^2).$$

Now CF$=r-\frac{1}{2}$G, CT$=r+\frac{1}{2}$G$-$J, OT $=\rho$; hence

$$(\mathrm{G}-\mathrm{J})(2r-\mathrm{J}-2\rho) =\rho[(r-\tfrac{1}{2}\mathrm{G})q^2-(r+\tfrac{1}{2}\mathrm{G}-\mathrm{J})p^2]$$

But in comparison with r, G and J may be neglected; the equation becomes

$$2(\mathrm{G}-\mathrm{J})(r-\rho)=r\rho(q^2-p^2),$$

$$\therefore\ \delta-d=\frac{m(q^2-p^2)}{2(\mathrm{G}-\mathrm{J})}.$$

When the curvatures are in opposite directions we have simply to change the sign of d. When the main line is straight $d=o$. In any case it is simply necessary to deduce δ, set out TF and make the point of concourse F.

3. Tables:

In the ordinary case $\mathrm{J}=5''$, $\mathrm{G}=4'\ 8''\tfrac{1}{2}$; whence

$$\delta-d=v(q^2.-p^2),$$

$$v=20025{,}71.$$

The following tables give the values of vq^2, vp^2 for various frog numbers and switch lengths:

No. of frog....	4	5	6	7	8	9	10	11	12
vq^2...........	1251.6	801.0	556.3	408.7	312.9	247.2	200.3	165.5	139.1

Switch Length.	8	12	16	20	22	24	26	28	30
vp^2...........	54.3	24.1	13.6	8.7	7.2	6.0	5.1	4.4	3.9

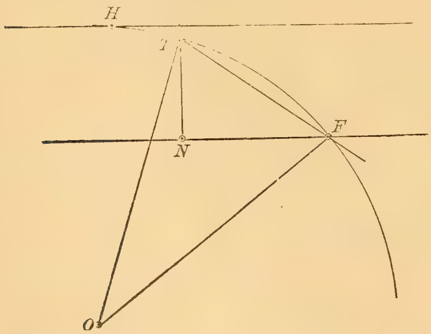
This table enables us to solve immediately any example that can occur.

(1) Given the original deflection angle 123′, the switch length 26 feet, the frog number 9, then $\delta-d=247.2-5.1=242'$; $\delta=365'$.

(2) Given the original deflection angle 94′, the switch length 30 feet, the frog number 6, then for a turn out on the convex side $\delta+d=556.3-3.9=552.4$, $\delta=458'\tfrac{1}{2}$.

Such are the "tedious and complicated calculations" which Trautwine dreads. [P.B. 404].

4. If the main line is straight the exact formulæ are very simple. Their employment is however attended with no advantage.



If in the figure the frog distance $\mathrm{TF}=f$, then since $o=q-p$, $\mathrm{TFN}=\tfrac{1}{2}(q+p)$

$$f=\frac{\mathrm{G}-\mathrm{J}}{\sin.\tfrac{1}{2}(q-p)}$$

$$\rho=\frac{f}{2\sin.\tfrac{1}{2}(q-p)}$$

5. Frog distance:

The first of these formulæ gives the approximate result

$$f=\frac{2(\mathrm{G}-\mathrm{J})}{p+q}$$

When $\mathrm{G}=4'\ 8''\tfrac{1}{2}$, $\mathrm{J}=5''$ this gives for f in feet

$$f=\frac{103}{12(p+q)}$$

It would not be difficult to show that this formula is approximate in defect, the proportion of error being about

$$\frac{(cp+q)^2}{24},$$

which in the most unfavorable case does not amount to more than 0,13 of one per cent. Accordingly it will be found that the values of f given in the following table are more precise than Trautwine's [P.B. 402] obtained it is presumed from an exact formula but by a more circuitous process:

(*See Table on following page.*)

§ 5. SYLLABUS OF FORMULÆ.

1. Exact formulæ:

$$\mathrm{L}r=\bar{1}.69897-\mathrm{L}\sin.\ d,$$

$$\mathrm{L}s=\mathrm{L}r+\mathrm{L}\ \sin.\ \mathrm{D},$$

$$\mathrm{L}t=\mathrm{L}r+\mathrm{L}\ \tan.\ \mathrm{D}.$$

	4	5	6	7	8	9	10	11	12
8	284	340	392	440	485	526	564	600	634
12	301	366	426	483	537	589	637	683	727
16	311	380	445	508	568	626	681	751	785
20	317	389	458	524	589	651	710	768	824
22	319	392	462	530	566	660	722	781	839
24	321	395	466	536	603	668	731	793	852
26	323	397	470	540	609	675	740	803	864
28	324	399	473	544	614	682	747	811	874
30	325	401	475	548	618	687	754	819	883

This table gives the values of f to the nearest tenth of a foot

2. Approximate formulæ:

$$dr=m,\ ds=S,\ dt=T,\ dn=D.$$

3. Deflection angle of a short chord:

$$d_x = dc_x$$

4. Long chord:

$$c_x = \frac{2S_{dx}}{d}$$

5. Middle ordinate in links:

$$y_0=\frac{8}{11}\cdot\frac{d}{100}$$

6. Cant in inches; common gauge:

$$H=\frac{22dV^2}{10^6}$$

7. Compound curves:

$$D+D'=\tfrac{1}{2}(A+A')=\omega,$$

$$d\sin. A'+d'\sin. A=\frac{m}{c}\cos.^2\omega+\frac{c}{m}dd',$$

$$d=\frac{m}{c}\sin. A.\ \frac{1-\frac{r'}{c}\cdot\frac{\cos.^2\omega}{\sin. A}}{1-\frac{r'}{c}\sin. A'}$$

8. Reverse curves:

$$D-D'=\tfrac{1}{2}(A-A')=\omega,$$

$$d\sin. A'+d'\sin. A=\frac{c}{m}dd'-\frac{m}{c}\sin.^2\omega,$$

$$d=\frac{m}{c}\sin. A.\ \frac{1+\frac{r'}{c}\cdot\frac{\sin.^2\omega}{\sin. A}}{1-\frac{r'}{c}\sin. A'}$$

9. Deflection angle of turnout from a curve:

$$\vartheta=\frac{m(q^2-p^2)}{2(G-J)}+d$$

For common gauge and travel 5 inches

$$\frac{m}{2(G-J)}=20025.71.$$

§ 6. EXAMPLES.

This section contains solved examples to illustrate the rules and processes of the method which has been explained.

1. Simple curve:—data, $D=18°\ 37'$; $d=2°\ 50'$

$$n=\frac{1117}{170}=6\frac{97}{170}=6.57$$

The curve therefore consists of six complete chords and a short cord of 57 links whose deflection angle is 97°. The radius 10.11 is taken from the table. And

$$y_0=\frac{8}{11}\times 1.7=1.2$$

Finally from the S—table

$$S=531.2+\frac{37}{60}\times 28.4=548.7$$

$$\therefore\ 2s=\frac{548.7}{85}=6.46$$

This or any other long chord may be used to test the precision of the field work.

2. Simple curve:—data, $s=10.32$; $d=1°\ 47'$

$$S=107\times 10.32=1104.2$$

$$\therefore\ D=39°58'$$

$$n=22\frac{44}{107}=22.41$$

$$r=16.37-\frac{2}{5}\times 7.4=16.07$$

$$y_0=\frac{8}{11}\times 1.07=0.8$$

3. Simple curve:—data, $s=8.42$; $D=11°$ $29'$

$$S=328.0+\frac{29}{60}\times 29.4=342.2$$

$$d=\frac{342.2}{8.42}=40.63 \text{ say } 40\tfrac{2}{3}$$

$$\therefore\ 2s'=2\times\frac{342.2}{40\frac{2}{3}}=16.83$$

$$n=\frac{689}{40\frac{2}{3}}=16.94$$

$$y_0=\frac{8}{11}\times 0.40\tfrac{2}{3}=0.3$$

It will be observed that the corrected chord $2s'$ falls 1 link short of the old chord. This variation is entirely admissible and unavoidable with a transit that reads, as is usual, only to 20 seconds.

4. Simple curve:—data $t=19.25$, $2D=48°\ 24'$

$$T=765.3+\frac{12}{60}\times 36.2=772.5$$

$$d=\frac{772.5}{19.25}=40$$

$$n=\frac{1452}{40}=36\frac{12}{40}=36.30$$

$$y_0=\frac{8}{11}\times 0.4=0.3$$

$$S=699.1+\tfrac{1}{5}\times 27.3=704.6$$

$$2s=\frac{704.6}{20}=35.23.$$

5. Compound curve:—data, $2c=8.43$; $A=14°\ 23'$; $A'=21°11'$

Assume $A=2D$; then

$D=7°\ 11'\tfrac{1}{2}$ $\qquad$ $D'=10°\ 35'\tfrac{1}{2}$

$$d=\frac{525\times 215.2}{4.215\times 316.0}=85$$

$$d'=\frac{525\times 316.0}{4.215\times 215.2}=183$$

$$n=\frac{431.5}{85}=5.09 \quad n'=\frac{1271}{183}=6.95.$$

6. Reverse curve:—data $2c=11.28$; $A=16°\ 24'$; $A'=10°\ 42'$

Assume

$$D=15°;\quad D'=1°\ 27';$$

$$d=\frac{402{,}7\times 444{,}9}{5{,}64\times 277{,}3}=114.5;$$

$$d'=\frac{402.7\times 42.0}{5.64\times 43.5}=69;$$

$$n=\frac{900}{114.5}=7.86. \qquad n'=\frac{87}{69}=1.23$$

7. Turn out:—$d=130'$; no. of frog, 8; length of switch, 24.

$$\begin{array}{r} vq^2=312.9 \\ vp^2=6.0 \\ \hline 306.9 \\ d=130.0 \\ \delta=437 \end{array}$$

The corresponding radii are 13.22 and 3.94. From a drawing made to scale the frog distance may be found approximately. It is best however to determine the place of the frog by setting out the turnout.

R—Table, Argument *d*.

	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	
0′	∞	2865	1432	955	716	573	478	409	358	318	0′
5′	34377	2644	1375	929	702	564	471	404	354	315	5′
10′	17189	2456	1322	905	688	553	465	400	351	313	10′
15′	11459	2292	1273	981	674	546	458	395	347	310	15′
20′	8594	2144	1228	859	661	537	452	391	344	307	20′
25′	6875	2022	1186	838	649	529	446	386	340	304	25′
30′	5730	1910	1146	819	637	521	441	382	337	302	30′
35′	4911	1809	1109	799	625	513	435	378	334	299	35′
40′	4297	1719	1174	781	614	506	430	374	331	296	40′
45′	3820	1637	1042	764	603	498	424	370	327	294	45′
50′	3438	1563	1011	747	593	491	419	366	324	291	50′
55′	3125	1495	982	731	583	484	414	362	321	289	55′
	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	

S—TABLE, ARGUMENT D.

	0	1	2	3	4	5	6	7	8	9	
0	0.0	30.0	60.0	90.0	119.9	149.8	179.7	209.5	239.2	268.9	0
1	298.5	328.0	357.4	386.7	415.8	444.9	473.8	502.6	531.2	559.6	1
2	587.9	616.0	643.9	671.5	699.1	726.4	753.5	780.4	807.0	833.3	2
3	859.4	885.3	910.9	936.2	961.2	985.9	1010.3	1034.4	1058.2	1081.7	3
4	1104.9	1127.7	1150.1	1172.2	1194.0	1215.4	1236.4	1257.1	1277.4	1297.2	4
5	1316.7	1335.8	1354.5	1372.7	1390.6	1408.0	1425.0	1441.7	1457.7	1473.4	5
6	1488.6	1503.4	1517.6	1531.5	1544.9	1557.8	1570.3	1582.2	1593.7	1604.7	6
7	1615.2	1625.2	1634.7	1644.0	1652.3	1660.8	1667.8	1674.8	1681.3	1687.3	7
8	1692.7	1697.7	1702.1	1706.1	1709.4	1712.3	1714.7	1716.5	1717.8	1718.6	8

T—TABLE, ARGUMENT D.

	0	1	2	3	4	5	6	7	8	9	
0	0.0	30.0	60.0	90.1	120.2	150.4	180.7	211.0	241.6	272.2	0
1	303.1	334.1	365.4	396.8	418.8	460.6	492.9	525.5	585.5	591.9	1
2	625.6	659.8	694.5	729.6	765.3	801.5	838.3	875.8	913.9	952.8	2
3	992.4	1032.8	1074.1	1116.2	1159.4	1203.6	1248.8	1295 2	1342.9	1391.9	3
4	1442.3	1494.2	1547.7	1602.9	1659.9	1718.9	1779.9	1843.2	1909.0	1977.3	4
5	2048.5	2122.6	2200.0	2281.0	2365.8	2454.8	2548.3	2646.8	2750.7	2860.7	5
6	2977.1	3100.9	3232.7	3373.4	3524.2	3686.1	3860.6	4049.5	4254.3	4477.7	6
7	4722.5	4992.0	5290.1	5622.1	5994.3	6414.9	6894.0	7445.3	8086.7	8842.8	7
8	9748.1	10853.	12230.	13999.	16354.	19647.	34581.	32797.	49222.	78221.	8

ON THE CAUSE OF THE BLISTERS ON "BLISTER STEEL."

BY JOHN PERCY, M. D., F. R. S.

Journal of the Iron and Steel Institute.

IN the process of making steel, which is so largely practiced at Sheffield, bars of iron, usually of Swedish or Russian manufacture are embedded in charcoal powder, and kept heated to bright redness during about a week or ten days, according to the degree of carburization desired. Carbon is thereby imparted to the iron, and steel is the product. The bars operated upon are generally about 3 inches broad and $\frac{3}{4}$ of an inch thick. How the carbon finds its way even to the center of such bars is a question not yet satisfactorily solved, though it possesses high scientific interest, and has been much discussed. It is not however my intention to consider that question on the present occasion; but to communicate to the Institute experimental evidence as to the cause of the singular phenomenon which accompanies this process of converting iron into steel, namely, the occurrence of blister-like protuberances on the surfaces of the bars. This appearance is so characteristic and so constant, that the name of "blister-steel" is applied to such bars. The protuberances are hollow, exactly like blisters, and vary much both in number and size: some are not larger than peas, while others may exceed an inch in diameter, and they are always confined to the surfaces of the bars, for I have a specimen of "blister steel" in my collection, in which there is a single blister as large as a small hen's egg, protruding equally from each of the flat opposite surfaces of the bar.

With regard to the cause of these blisters there has been a difference of opinion. I will take the liberty of making the following quotation on the subject from my volume on "Iron and Steel," published in 1864:—"They (*i.e.*

the blisters) appear to be due to internal local irregularities and gaseous expansion from within, while the iron was in a soft state from exposure to a high temperature. There is no doubt that all forged bars, for reasons previously assigned [and which I stated in considerable detail], contain more or less interposed basic silicate of iron irregularly diffused throughout. Now, what should be the effect of the contact of carbon, at a high temperature, with particles of this silicate? Most probably the reduction of part of the protoxide of iron with the evolution of carbonic oxide, and if this be so, then it seems to me, the formation of blisters may be satisfactorily accounted for. Admitting this explanation to be correct, a bar, which has been made from molten malleable iron, should not blister during cementation [the term used to designate the process in question of making steel]; and, should this prove to be the case, it would not be difficult to prepare such a bar with particles of cinder [ferrous silicate] imbedded, and by subsequently exposing it in a converting furnace, ascertain positively whether blisters would occur only in places corresponding to the cinder."

It has, I think, been conclusively proved that all bar iron manufactured by charcoal finery processes, or by puddling, must contain, intermixed, some of the slag, which results from the conversion of pig iron into malleable iron by such processes, in which, let it be remembered, the malleable iron is never actually melted. In the quotation which I have given I mentioned only ferrous silicate as constituting the slag; but I ought, also, to have included free oxide of iron, doubtless magnetic oxide. The bars converted at Sheffield are chiefly Swedish, and are generally manufactured by the so-called Lancashire process.

On a visit to the great steel works of Messrs. Firth, at Sheffield in February last, Mr. Charles H. Firth was so good as to undertake, at my suggestion, to settle the question whether blistering would occur in the converting process in the case of a bar of iron which had been actually melted, and so freed from all intermixture of ferrous silicate, or magnetic oxide of iron. The experiment was accordingly made, and with good effect, of confirming, and, I think I might almost say, establishing the correctness of the explanation which I ventured to submit concerning the cause of the formation of the blisters. On the 9th of last May, Mr. Firth informed me that he had melted Swedish bar iron, and cast it into a flat ingot, which he had carburized in the converting furnace in the usual manner; and, at the same time, he forwarded to me a piece broken from the ingot, after conversion: this piece was about six inches long, three inches broad, and a little more than half an inch (exactly $\frac{7}{12}$) thick; it showed a fracture at each end characteristic of converted steel, but there was not the slightest indication of a blister.

The other experiment, which I suggested, seems scarcely to be needed, namely, that of cementing a cast bar of malleable iron, in which bits of slag, or magnetic oxide of iron, had been imbedded. But should any one be willing to make such an experiment, probably the best way would be to cast an ingot of Swedish iron, drill a hole or two in it to the depth of about the center, insert a bit of slag in one hole, and a bit of magnetic oxide of iron in another, then plug up the holes hermetically by a screw or otherwise, and convert in ordinary way.

THE STRUCTURAL PROVISION FOR THE DISCHARGES OF THE RAINFALL OF LONDON.

From "The Builder."

The serious damage and discomfort inflicted on so large an area of London by the rain of the night and morning of the 10th and 11th of April afforded a subject of very serious contemplation to all who are engaged in building, or in dealing with that first duty of the architect, the art of keeping houses dry. It is satisfactory to find that the first account which was published of the burst-

ing of a main sewer in the Brixton-road has been subsequently contradicted, and that it was not to the failure of any portion of the Main Drainage works, in as far as their structural strength was concerned (that is to say, as a question of strength apart from the question of capacity), that so serious a misfortune is to be attributed. At the same time, it can hardly be argued that the inhabitants of a city like London ought to be exposed to those floods and watery disasters which have of late been but too common in the southern portion of the metropolis. Convulsions of nature, indeed, may be beyond the forecast of human wisdom to prevent or to render harmless. Thebursting of a water-spout, or the violent down-pour occasioned by a throw on a low-lying district a mass of tornado, may water that will for a time choke up the best engineering arrangements for outfall. The rain of the night of the 10th of April, however, was by no means of so altogether exceptional a kind as is called a meteoric phenomenon. It was heavy, continuous and prolonged, rather than sudden and violent. Its fall was stated at two inches in London streets (and as much as three inches at Greenwich) in about nineteen hours, a quantity which, while giving a quantity of 200 metric tons per acre, is not so great that it should overtax our means of discharge. Double the former depth of rainfall was gauged in some parts of England in the wet time some two years ago. At all events, it is an amount of rain for which experience tells us that we ought to provide, and the possible occurrence of which was distinctly referred to by the engineer of the Main Drainage works as having been regarded as possible. It would be a deplorable outcome of the engineering science of the nineteenth century for us to be told that when two inches of rain falls within twenty-four hours, or when an east wind comes at the back of a high spring tide, the inhabitants of a large part of London are to resign themselves to partial submergence, with all the damage to property, as well as to health, involved in such a calamity. But unless the recent disaster be taken up by the public and by the press with rather more persistence, as well as with rather better information than was the case with regard to the last floods, little practical good will be derived from so costly a lesson.

The subject is so immediately connected with the primary structural and sanitary question of the proper method of securing an outfall for storm-water, that it may be instructive to glance at the physical features of London, immediately to the south of the Thames, and at the change in the course of the outflow of rainfall that has been effected by the Main Drainage works. The river Thames, from the confluence of the Wandle at Wandsworth to that of the Ravensbourne at Deptford, makes an irregular triple curve, or series of three loops, to the north, running at an extreme distance of as much as 2½ miles from the chord of this compound arc. There are reasons for supposing that the ancient bed of the river took a more direct line than that of the present channel. At all events, the whole area which we have described lies below,—some of it as much as sixteen feet below,—the contour line of ten feet above Trinity high-water mark of the year 1800,—a level which high tides now not unfrequently surmount. The ground was marsh, so recently as the Restoration; and is represented as such in an engraving of the entrance of King Charles II. into London, which exists in Mr. Gardner's remarkable collection of drawings, engravings, and other publications illustrative of the history and architecture of the metropolis. Gradually, as the progress of population covered this marshy site with building, the house-drainage became a source of more and more disquietude. The low-lying area above indicated covers as much as twenty square miles. It is in places as much as five feet or six feet below high-water mark. The sewers which, since the year 1815, were gradually constructed so as to run mostly in an easterly direction, into the Thames, had but little fall, and, except at the period of low tide, were tide-locked and stagnant. After long-continued rain they became overcharged, and were unable to empty themselves during the short period of low water. Many days, therefore, often elapsed during which the rain accumulated, and the sewage was forced into the basements and cel-

lars, to the destruction of much valuable property, and to the great loss of health among the residents.

There is no doubt that a considerable benefit has been conferred on this district by the works of the main metropolitan drainage, even though these works have proved inadequate to the discharge of a steady rain like that of April 10th, 1878. It was the design of the works to arrest the torrent water before it descended into this low-lying district. For this purpose two lines of sewer were constructed, one approximately parallel to the course of the river, and the other approaching the line of the first at an acute angle. The first, or main line, commences at Clapham,—the second, or branch, at Dulwich. Between them they drain an area of about twenty square miles, including Tooting, Streatham, Clapham, Brixton, Dulwich, Camberwell, Peckham, Norwood, Sydenham, and part of Greenwich.

It was stated in the original report as to these main sewers that they were of sufficient capacity to carry off all the flood-waters, so that they would be entirely intercepted from the low-lying districts, which were thus to be protected from floods. The falls of the main line are fifty-three feet, twenty-six feet, and nine feet per mile to the Effra sewer at the Brixton-road, and thence to the outlet $2\frac{1}{3}$ feet per mile. The old course of the Effra fell into the Thames near Vauxhall Bridge. The diversion of this torrential channel so as to flow into the Thames at Deptford is in accordance with the principles of outfall drainage laid down and followed out by the Rennies, and by the most able and distinguished engineers. But the combination of a torrential diversion with a main sewerage drainage is another matter. As a question of quantity alone, it is now manifest that the sectional area, varying from a barrel of seven feet in diameter to a section of ten feet six inches by ten feet six inches with a circular crown and segmental sides and invert, is not adequate to the discharge of a quantity of rain which is not more than half of that which has been known to occur in some parts of the country, in twenty-four hours, within the last two years. The sectional area of a seven foot barrel is, say, forty square feet. We may take that of the larger section as about eighty square feet. A fall of two inches of water, in twelve hours, over an area of twenty square miles, gives a flow of 2,085 cubic feet, or 13,000 gallons, per second, which would require a velocity of about sixteen miles per hour in order to be discharged through a culvert of the larger of the two sections named,—a velocity which is practically impossible. This calculation must be confronted with the fact that in proposing to turn the storm water of London into the main sewerage, the engineer considered that a rainfall of $\frac{1}{4}$ inch per day, in excess of the maximum flow of the sewers, was all that had to be provided for. Sir J. Bazalgette, in his report on the Main Drainage system in March, 1865, stated with perfect truth that "there are, in almost every year, exceptional cases of heavy and violent rain storms, and these have measured one inch, and sometimes even two inches, in an hour." The maximum flow of sewage is estimated, in the report cited, at a volume equal to that produced by a rainfall of 80.01 inch per hour, or, as above mentioned, 0.25 inch in twenty-four hours. As a rule, then, the area of the sewers has been doubled, in order to provide for an arbitrarily restricted quantity of rain, amounting to less than an eighth-part of that which was known occasionally to occur.

"But," the report continues, "exceptional rain storms must be provided for, however rare this occurrence, or they would deluge the property on which they fell."

This brings us to the point of which the due appreciation is rendered so urgent by the disaster of the 10th of April. The question of the provision for storm-water, or excessive rainfall, is one of the most serious that can demand the attention of the architect or of the engineer, especially in the case of a large city. In those parts of the world where rain of from one inch to two inches or even more per hour, is not uncommon, the architect is compelled by necessity to look facts in the face, and to provide for the safe discharge of what would otherwise prove destructive floods. Thus in the south of Europe the streets of the principal cities are so constructed that they offer ready and efficient channels

for the torrents that spring up in formidable volumes after an hour or two of rain. In Turin, in Naples, and in other cities, the arrangements for this purpose are very effective. It is true that they are not complicated by being mixed up with the scavenger drainage of the cities. But that is the very point at issue. The question is, ought the rainfall to be turned into the sewers?

In cases where no regular artificial water supply is provided for a large collection of dwellings, but where the sewage of the houses is carried off by underground culverts, the utilization of the rain water, at least in part, for the flushing of the sewers is indispensable. That much may be freely admitted as necessary in the interests of sanitation. But one of the main objects in the supply of a volume of water varying from twenty-five to forty gallons per head of the population per diem is to provide a regular and adequate amount of water carriage for the removal of the sewage. The most that can be said in favor of the admission of storm water into the sewers, as far as the sanitary service of the population is concerned, is that it will not materially affect the regularity of the daily discharge. With such a supply of water as we have named, there is no need for flushing at irregular and uncontrollable intervals. The two systems are not only different, but inconsistent. When rain is depended on for flushing, an arrangement is proper that differs materially from that which is suited to the discharge of a regular daily quantity of diluted sewage. When the latter is properly provided for,—when the inflow of the water runs through a well-devised system of pipes, and the outflow of the same water, bearing with it the refuse products of city life, is carried on through a proper series of pipes and culverts, any capricious excess of quantity, such as that arising from storms, only complicates matters. If, on the one hand, the sewers be provided so large as to deal with, not only the ordinary but the extraordinary rainfall, their dimensions must be so large as to cause an enormous expense. The figures above given will show that something like sixteen times the sectional area that is required for the daily regular service must be added to that section in order to give anything approaching certitude as to dealing with storm water; although the occasions on which that section would be filled will be very rare.

We are not about to pronounce an *ex cathedra* opinion on a subject as to which different views are entertained by professional men of experience; nor do we wish to offer any criticism as to details of the existing arrangements. It is rather our object to elicit general principles as to the truth of which debate is unnecessary; and to point out the practical result of the application of these principles. Such, we conceive, is the useful and important function of the scientific press; and such the line which should divide the remarks of a public writer from the report of a consulting engineer.

It is certain that, in providing for the drainage of a town or city, one of three courses must be taken. Either the rainfall and storm-water must be excluded from the sewers, or it must be accommodated by them, or there must be a more or less perfect combination of the two systems; that is to say, part of the rain will be, and part will not be, carried off by the sewers.

Of these three methods, the second, which is the simplest, is supposed to be excluded from consideration on account of its expense. In the case of London, for example, instead of being designed of a capacity, as at present, to carry off twice the maximum flow of sewage, the sewers, in order to be efficient under any stress of weather, must be of a size to carry off at least seventeen times that volume. Even this considerable additional cost, however, is not the main difficulty. Sixteen times the discharging area of channel would not imply sixteen times the cost of construction, although it would no doubt involve $2\frac{1}{2}$ times as much outlay, or even more. But the real difficulty, in the case of London, lies in the fact that the entire extra volume has to be pumped up for a height of 36 feet in order to enter the Thames. There is indeed, an outfall for storm water provided at Deptford, but there is, even at that point, a lift of 18 feet from the low-level sewer. If we take the smaller lift alone we still find that either the capacity of the pumping apparatus must be so arranged as to enable it to deal

with a sixteen or seventeen fold quantity of water, on a sudden emergency, or that the enlarged sectional area given to the sewers would be of no value as a protection to the district. Practically, there fore, the provision for the whole of the storm water by the sewers is pretty well out of the question.

If we take the opposite view, namely, that the storm water should be excluded from the closed system of water supply and of sewage we commence with the advantage of a diminution of cost, and better sewers as respects sewage alone. Both as regards the pumping apparatus, half the actual provision would on that system have been adequate.

The question, however, would then have arisen, How to deal with the rain? But this very question is no less important, and, we must be allowed to say, is not brought much nearer to a satisfactory solution, under the adoption of the the present plan, which is one of a mixed character, accommodating a part of the rainfall in the ordinary sewers, and providing (or rather as it seems not providing) for the remainder by supplementary works.

It is well to observe that the suffering caused by the flood of the 11th of April is by no means confined to the district drained by the Metropolitan Board of Works. The area of the rainfall was limited. Although it rained during the night over large part, and probably over the whole, of the water shed basin of the Thames it was on approaching London that the traveler became aware of anything like a phenomenal rainfall. More rain fell on the north than on the south of London. The river Wey was not unusually, full at the time when the rivers Colne and Brent were bringing down exceptionally high floods. The Medway also was greatly swollen. Thus, if we take the case of Brixton as one most fit to be examined, it is not to be thought that the diversion of the Effra is a sole cause of difficulty; although it may afford an unusually forcible illustration of the operation of the mixed system of outfall at present in vogue.

The principle of the existing works for the drainage of London is thus stated by Sir J. Bazalgette. "As it would not have been wise, or practicable, to have increased the size of the intercepting sewers much beyond their present dimensions, in order to carry off rare and excessive thunderstorms, overflow weirs, to act as safety valves in times of storm have been constructed at the junctions of the intercepting sewers with the main valley lines. On such occasions the surplus water will be largely diluted, and after the intercepting sewers are filled, will flow over the weirs, and through their original channels into the Thames." How far this plan has been adhered to in the case of the Effra line of drainage we shall, perhaps, learn from the report which Sir J. Bazalgette has been directed to prepare. But the report of 1865, from which we are quoting, says further, "The old Effra sewer. which fell into the river near Vauxhall Bridge, has been diverted, through this (the intercepting) sewer to a new outlet at Deptford, and the old line has been filled in and abandoned." There seems to be some contradiction between these two passages of the report; and we are thus unable at the moment to ascertain how far the principle of allowing an overflow to take the course of the original outfall has been carried out in the case of the Brixton sewers.

Whatever be the arrangement in this particular instance, it is evident that the safety-valves provided have been entirely inadequate to carry off an amount of rain that may at any time descend on London. This, however, is, in our opinion, by no means the most important part of the question. It is one thing to have drainage that works very well on ordinary occasions, but that breaks down in a storm, and another matter to have a system that adds to the mischief of a storm that of a widespread pollution by sewage. The expression "the surplus waters will be largely diluted" contains the marrow of that to which we object on sanitary as well as on economical grounds. If a system of sewers is so constructed as to be capable of conveying only a fraction of an unusual rain fall, it ought to be the care of the engineer that no excess over that fraction should be allowed to enter the sewers. By entering in detail the contributory drains, sweeping them of their contents, filling the intercepting lines, and then overflowing not only through streets but through houses, the rain takes the most

mischievous and disastrous course into which it can possibly be turned.

We confess that this consideration has very great weight in inclining us to the opinion that, all things considered, economy, as well as public health, would be consulted by the systematic exclusion of the rainfall from the sewers. It is certain that if the whole of the rain be turned into this channel of discharge, and if the latter proves at times totally inadequate to carry it off,—the worst kind of evil remains. The limitation of the ingress of the rain is a more difficult matter than its total exclusion.

The question then would arise, it may be urged, how to provide for the rainfall? But this is the very question which is involved under the mixed system. The mixed system provides, let us say, for 364 days out of the year, but breaks down under a deluge on the 365th. Somehow or other we are bound to provide for that exceptional 365th day. The question is, can we not most surely, most thoroughly, and most economically provide for the entire disharge of the rain whether normal or abnormal without turning it into the sewers?

We prefer to put this question as a suggestion. We take it for granted that London has the right to claim an effectual protection from floods, whether arising from the Thames, or poured down from the surrounding water-shed. At the present moment there can be no doubt that the expenditure of nearly eleven million sterling in drainage and embankment works has placed large districts of London in a far worse position, when exceptional floods occur, than they were in fifty years ago. It is stated in the report by Mr. Redman, to which we have before referred, that the height of the Thames floods has been increased by the Embankment on the north of the river. It is clear from the reports of the late disaster that the action of the southern drainage works has been such as to pollute the torrent water that overflowed streets and houses with sewage. These are results of a mixed system, which, to our minds, has a fatal flaw. It is that of being a fine weather system alone. Would it not be better to look foul weather in the face? Would not a system that should provide specially for rainfall, whether it be 0.01 inch per hour or 0.25 inch per hour, fully and simply, without choking the sewers, or overpowering the pumping engines as soon as the lower dimension was much exceeded, be the most economical, as well as in all other respects the best.

For the discharge of rain, not by the sewers two modes are possible,—which of course, may be combined according to circumstances. One is the original method, which is capable of very admirable management, of making the roadway form channels, or a channel, for the rain. The other is that of constructing special subways, for culverts, for that purpose. The city of Turin is subject to violent rain. Storm clouds collect over the Alps, and after two or three days of intense heat often burst in a sudden deluge on the city. The violence of the rain is far greater than any to which we are accustomed in this country. But the architects and surveyors of Turin have made such provisions that the rain comes as a friend, not as a destroyer. The streets are carefully paved for the most part with broad lines of dressed stone for the wheels to run over and intermediate pitching for the horses, edged with raised footpaths, and pierced with gully-holes at certain appropriate points. It is by no means unusual to see from 2 inches to 3 inches of water running over one of the main streets of Turin after half an hour's rain. But all that follows is, that for so many minutes a clear bright stream of that depth runs along the road. By the time that the storm has ceased, and pedestrians and carriages can venture forth from the shelter to which they were driven, the rain has run off as rapidly as it at first rose, and a clean street is all that remains to tell of the downfall.

In Naples more formidable torrents find their way through the city in storms, owing to the greater amount of catchwater area which intervenes between the city and the crest of the Apennines. The sirocco, a southern wind, brings a tropical fall of rain, not only over the city, but over the country for miles round. To protect the city there is a large intercepting *fosse*, or moat which is practicable as a road in dry weather but which becomes a veritable river in storms. Besides this, the streets are arranged in accordance with the lie of the

land, so as to carry off the water. In some places pavement, as in Turin, leading to culverts at proper places, prevents any permanent inconvenience from the results of a tropical downpour. But in others and notably in the road leading into Naples from Caserta, a wide street dips gradually towards the center, in which is a paved open channel, dry, except in time of rain, and readily carrying off any moderate quantity of water. But when a sirocco deluge comes on, a vast body of water seeks this channel. The inclination of the sides of the streets is such as to allow the gradual widening as well as deepening of the torrent, in proportion to the exigencies of the moment. In the utmost volume of the rain the sides of the street remain above the flood, and light iron bridges, under which it is easy to drive in fine weather, afford means of crossing to pedestrians when the central part of an important thoroughfare is converted from road into river.

The conditions of the Italian cities are far more severe, as regards liability to floods, than any that prevail in England. For that reason Italian architects have have been obliged to look flood in the face, and to provide for its ready discharge. For that reason no one in Naples or in Turin suffers any inconvenience from violent storms, beyond the risk of a wetting if he ventures out in them; for an umbrella is but a child's toy if opposed to an Alpine storm or to a sirocco shower. That similar arrangements might be introduced into the streets of London cannot be questioned by men of foreign experience. That by a thorough consideration of the worst possible case, the means of providing for the discharge of an inch of water in an hour, London might be rendered perfectly safe against a rain flood, will not be doubted by any who gives attention to the subject. That a due consideration of what is needful in extreme emergency would lead to a provision that would at all times be efficient, and that would take a great load off the whole system of sewerage and of pumping, is the thesis that we submit for consideration. As we must provide for the worst—under penalty of extraordinary loss—is it not better to do so in the first instance and at the same time to arrange for the discharge of all our rain water, whether it be an inch, or a hundredth of an inch, in an hour, without inflicting on the works of the sewerage a duty that may at any moment rise to the double of the necessity amount of work, and which, as soon as it exceeds that double, commences the work of disaster?

THE PURIFICATION OF WATER.

By GUSTAV BISCHOF, F.C.S.

From "Journal of the Society of Arts."

THE subject which I have the honor to bring under your notice to-night is of a somewhat embarrassing magnitude, though it is my intention to confine myself solely to the purification of water for sanitary purposes. It would be easy to lay before you a number of facts and conclusions bearing on the means by which this may be more or less effected, but it would be almost like building a house without foundations were I not first to attempt an understanding between us, or, at least, to explain my views as to the nature of the work which a purifier of water has to perform.

Absolutely pure water, containing exclusively oxygen and hydrogen in the proportion in which they chemically combine to form water, is not known, even in our laboratories. The foreign matter in ordinary water is either gaseous, mineral, or organic.

The gases which generally occur in water, namely, free oxygen, nitrogen and carbonic anhydride, are, in moderate quantities, not only harmless but even desirable. Oxygen and carbonic anhydride render water sparkling and palatable. It is chiefly to them the so-called mineral waters owe their palata-

bility, and they appear to have a beneficial effect upon the digestive organs. Other gases, such as sulphuretted hydrogen, indicate organic impurities and are objectionable.

Whether hard or soft water be more conducive to health has not been definitely settled, but probably a moderately hard water is more wholesome than either excessively hard or soft water.

Of greater consequence are the impurities of organic origin, consisting of living or dead animal or vegetable matter. These occur in water partially as solid particles in a state of suspension and partially in solution. Suspended impurities may be separated to a certain extent by mechanical filtration through sand, paper, or other materials. However, even in the brightest water, solid bodies are frequently discovered under the microscope, or by passing an electric ray through the water, as I will by-and-bye illustrate experimentally. These microscopic solid bodies are extremely minute in their largest sizes, the smaller objects remaining probably unseen, even by the aid of our most powerful microscopes. They are, therefore, not unfrequently considered amongst the matter which is in a state of solution. If these bodies are of an organized nature, we have in all probability to search amongst them for the virus which produces a number of the most disastrous diseases.

This naturally leads me to the germ theory. Whether and how far germs are at the root of disease, or whether the latter are due to common chemical agencies, is a much contested question. And yet it is a matter of considerable importance, upon which the decision hinges, whether we may depend upon the laws of chemistry in deciding any question relating to water supply, or whether this belongs more or less prominently to the physiologist. Being myself a believer in the germ theory, I wish to lay before you a few arguments, however incomplete they necessarily must be. We designate as contagia such parasitic infectious agencies as are transferable from one individual into the healthy body of another; there, we suppose, they multiply, when finding a favorable nidus, and produce a specific disease, similar to the one from which they originate, such as cholera or typhoid. What evidence, then, tends to demonstrate the organized nature of these contagia? They have never been with certainty isolated, no one has ever seen them, and yet, if we find that they are endowed with properties peculiar to living bodies, we can hardly evade the conclusion, that they themselves belong to a class of organisms. I think we shall agree that the property of producing their like by separation of part of their body and of growing by assimilation of extraneous matter, is peculiar to organized beings. Let us, then, see whether contagia exhibit any evidence of such properties. Chauveau has proved experimentally that the virus of small-pox, sheep-pox, and glanders is independent of quantity. The minutest particle, such as can only be obtained by great dilution, produces the disease with apparently the same virulence as concentrated matter. The remarkable epidemic of typhoid at Lausanne (Switzerland) in 1872, is, on the other hand, a practical demonstration, amongst many others, that the virus of typhoid produces fearful results in a state of dilution, in which the deadliest of the known chemical poisons would, as a matter of certainty, have had no effect whatever. Is it not probable in the highest degree, that we have to account for that apparent independence from quantity by a power of reproduction and rapid self-multiplication?

Again, the direct connection between cholera, or typhoid, and preceding cases of the same disease, has in so many instances been traced as to justify in my opinion the conclusion that nobody has ever been attacked by either of them, unless the specific virus had been transferred to him originally from a person afflicted with the same disease. It is, of course, out of my power to substantiate this to-night, by detailing a great many instances, but I may suppose that most, if not all, of you are familiar with them. Such unvariable connection can scarcely be explained, except by assuming that the virus possesses the peculiarity of organized beings of self-reproduction, in other words, as Dr. Simon expresses it in one of his reports to the Privy Council, that contagia multiply, in case after case, their respective types, with a successivity as definite and identical as that of the highest order of animal or vegeta-

ble life. Indeed, unless we assume this, we cannot understand the constant relation to a parent case and the total absence of any *de novo* generation by chance or coincidence.

There are, further, numerous instances of epidemics which appear to prove almost to demonstration that the virus of typhoid is peculiarly virulent, when gaining access to our milk supply. Similarly we have reason to believe, that the virus is more active, when passed into water largely contaminated with organic matter, than when passed into comparatively pure water. This is at once explained, if we assume that the virus is capable of assimilating organic matter, in fact, of living upon it.

In cases of poisoning by known chemical agencies on the other hand, say, by lead, the poison is not transferable from person to person; and whenever certain conditions are given, such as water of a certain composition passing through lead pipes, any person may, on drinking that water, be poisoned without any reference to a previous case. Small, but traceable, quantities of lead have frequently been found in the blood, liver, and other human organs, without any distinct injury to the system. Minute quantities of lead have sometimes been taken habitually for years, until the poison gradually accumulated to an extent sufficient to cause serious disorders, or even death. In his standard work on Hygiene, the late Dr. Parkes says with reference to this :—"On the whole it seems probable, that any quantity over 1-20th of a grain (of lead) per gallon should be considered dangerous." Such poisons therefore are not independent of quantity; on the contrary, let me also remind you, some of the strongest chemical poisons, such as strychnine, arsenic, lead, copper, and morphia, are given in small quantities as remedies against various ailments. Thus there appears to exist a sharp and remarkable contrast between ordinary chemical poison and the virus of cholera, typhoid, and similar diseases.

Dead organic matter forms a large proportion of ordinary filth, and all kind of filth is more or less liable to contaminate our water supplies. Those diseases, which are produced by common septic ferment, or by the ordinary putrefactive changes which dead organic matter undergoes, are therefore of peculiar interest to us.

As far back as about the middle of last century, Albrecht von Haller demonstrated that putrescent organic matter in aqueous solution may be fatal, if injected into the veins of animals. The symptoms he observed are, inflammation of the digestive organs, and disturbance of the nervous system. The animal heat is sometimes considerably increased, sometimes decreased. Panum succeeded in extracting a poison from putrid matter, which he describes as soluble in water, insoluble in alcohol, and free from albuminous matter. It is not destroyed at a boiling heat, and acts apparently like ordinary chemical poisons, the virulence being proportionate to the quantity injected. Arnold Hiller, on the other hand, has recently extracted an albuminous body from putrid meat by means of glycerine, which is precipitated and destroyed at a boiling heat, and soluble in alcohol and acids. On being injected under the skin of a rabbit, the extract, in which Hiller failed to discover any organisms, showed no effect for several days. Then, apparently after the ordinary period of incubation, the symptoms of blood poisoning made their appearance until the rabbit died. The poison was reproduced in the body of the animal, and by transferring it from rabbit to rabbit, Hiller calculated that in the tenth generation 1-120th of a drop of the original glycerine extract was sufficient to kill a rabbit in fifty-two hours. The symptoms were, fever, asthma, increased solution of the red blood corpuscles and diarrhœa. If Hiller's observation was conclusive as to the absence of organisms in the original extract, common chemical poison would appear capable of producing effects which I have endeavored to show can only be attributed to living organisms. But I venture to suggest, that the absence of the lowest forms of organic life, or their germs, can, at the present time at least, be hardly proved conclusively, excepting by the absence of their ordinary visible effects, for there is certainly evidence of life beyond the power of our microscopes, and we cannot know what we might see if their magnifying power were increased ten or a hundred fold. The disastrous conse-

quences which must be expected from the drinking of water, which is polluted by fermenting organic matter are, at any rate, illustrated by Hiller's experiments.

Upon what condition, then, does the wholesomeness, of a water supply depend? I cannot answer this by simply classifying the different sources of supply in one way or another, and laying down a rule that such and such sources are objectionable, or require purification, because those sources, which generally furnish an excellent supply, are sometimes contaminated and *vice versa.* But water must always be looked upon with the more suspicion the greater its liability to contamination by sewage, and more especially by human discharges, as these may carry with them the most dangerous specific seeds of disease. Thus, shallow well and river water are generally most largely polluted, whilst at the same time they are very extensively used for water supply. If we find these two attributes, namely, extensive use and pollution combined, it is worth our attention to inquire somewhat more closely into the alleged danger arising from the use of rivers and shallow wells as sources of water supply.

Rivers are generally largely fed by polluted surface water from cultivated land, and by vast volumes of sewage and other polluting waste materials. In the Registrar General's returns we read from time to time that a variety of most disgusting matter may be traced in Thames water, not only at the intakes of the several water companies in London, but even after filtration through sand, although the water is then mostly free from disagreeable smell or taste. From this we see that we cannot rely upon the outward appearance, the brightness, palatability, or absence of color and smell, in forming an opinion of the wholesomeness of a water.

The danger arising from the drinking of river water, especially in times of epidemics, is well illustrated by the experience of Glasgow. The mortality there, per 10,000 of population, during the three cholera epidemics of 1832, 1847, and 1854, was respectively, 140, 106, and 119, or, on the average, 122. During this period the water supply was derived exclusively, or almost exclusively, from the Clyde. Then followed the epidemic of 1866, after, in the meantime, the Loch Katrine water had been introduced. What was the result? The mortality from cholera decreased from the average of 122 to only 1.6, or to less than one and a half per cent. of that figure. There is no showing that this can be attributed to any other cause than the abandonment of the Clyde as a source of water supply.

Do not believe that this is an exceptional case. A glance at the map appended to the Sixth Report of the Rivers Pollution Commission will show the infinitely small area, which, excepting the Scotch Highlands, is covered by unpolluted river basins.

I have not been able to lay hold of any experimental proof in favor of the hypothesis of self-purification, of at least our English rivers, by oxydation; but in the Sixth Report of the Rivers Pollution Commission we find rather the reverse. The dilution, to which sewage is being subjected in rivers, may be a safeguard, to some extent, against common filth; but if contagia be organized bodies or individuals, dilution offers, in all probability, no protection against propagation of disease by their agency. This, I think, must be followed from the experience gathered during the epidemic at Lausanne, to which I have already referred, and from other instances. It follows also, from a consideration of the extraordinary power of multiplication which, at any rate, some of the lowest forms of organic life exhibit. Thus, F. Cohn, a great authority on these matters, has calculated that one single bacterium might, within less than five days, fill up by its progeny the whole ocean, supposing they found a sufficiency of food.

The remarks about river water apply also more or less to shallow well water. A striking illustration of the dangerous character of this source of water supply was furnished by the epidemic of typhoid in Broad Street, London.

It is impossible, within the time at my disposal, to enter into any more particulars as to the different sources of water supply, but I wish to offer a few general observations on this point.

It is not sufficient that a water supply should be generally of a more or less satisfactory quality, nor that its average state should not give rise to any serious

apprehensions. Otherwise, we would find ourselves unprepared and unprotected when the worst condition arrives, or when owing to the prevalence of epidemics, more than ordinary precaution should be required. In illustration of this, I believe that at ordinary times there is no actual danger in drinking, almost throughout the year, the water supplied from the Thames to the greater part of London, if it is sufficiently filtered through sand. This must be accepted in the face of the comparatively low mortality we have. But now and then, especially in times of floods, the water deteriorates, sometimes very seriously, and we even read of excremental matter being then traced in it under the microscope. This is certainly quite serious enough; but I ask you, is there any guarantee whatever that, should London be visited by an epidemic, our experience would be any better than that of Glasgow during the Clyde water period? It would, therefore, certainly be a great boon could we here have a water supply as pure as that from Loch Katrine; but, as long as this appears impracticable, we ought at least to have some additional means beyond those at present employed of purifying Thames water during certain periods of the year, and during epidemics.

By-and-bye I will return to this point, but in the meantime let me direct your attention to some of the most prominent materials employed in the purification of water. Some have either exclusively or prominently a mechanical action, separating like a fine sieve the coarser particles of suspended matter; others act chemically upon the foreign mineral or organic matter, and reduce the latter more or less to harmless constituents.

The organic matter retained by mechanical purifiers must gradually undergo decomposition, and the water, in passing through them, takes up more or less of the decomposing matter. It is thus intelligible that such a water may, physiologically speaking, be impurer, and may be less wholesome after, than before, filtration, should even chemical analysis indicate an improvement. To this class of materials belong mainly sand and wood charcoal, though the latter for a very short time has also a slight chemical action. The more frequently the materials are changed, and the more they are aërated during filtration, the more perfect will be their purifying action.

With the exception of animal charcoal and spongy iron, I have not been able to lay hold of any conclusive evidence of the efficiency of the materials proposed as chemical purifiers. They both have been extensively used in domestic filters.

The success of any material used for domestic filtration largely depends upon the arrangement of the filters in which they are used. These should be as easily manageable, and as simple in construction, as is compatible with efficient working. In insisting upon the former, let us not overlook the latter portion of this sentence. The remark that absolutely pure water is not known, even in our laboratories, sufficiently explains that the purification of water is not a simple or easy operation, the efficient performance of which must be expected to give some little trouble. The easiest and simplest way is, after all, not to filter water at all, and it is but reasonable to expect that its purification should be in some ratio to the care we bestow upon it. We should, therefore, not be satisfied to leave the filter entirely to the care of servants, or even frequently without giving them any guidance how they are to manage it.

In all domestic filters easy access should be given to the user himself for cleaning and recharging, as it is indispensable that chemical purifiers should be renewed from time to time, and, as a rule, the more frequently they are renewed the better. Instead of the renewal, a cleansing of the material is sometimes recommended, by passing the water through the filter in the opposite direction to that ordinarily employed. By these means a passage may be opened for water through the filtering medium, however its pores had been clogged with filth, but the latter will never be removed efficiently. If any one doubt this, let me remind him of the difficulty which we find in keeping even the smooth surface of our slate cisterns in a clean condition. The slimy deposit adheres most tenaciously, and must adhere still more tenaciously to a granular, more or less porous, material. How often a material

requires thus to be renewed depends, largely, upon the energy of its chemical action upon organic matter.

If these considerations are conclusive, I must condemn all filters in which the materials are enclosed between slabs, which are cemented into the filter case; as this, by not giving access to the contents, encourages the undue prolongation of their use. From the same point of view, all materials are objectionable which, being in the form of porous slabs or balls, are not accessible throughout their mass. And, just in passing, let me warn you against the use of sponges, which, although excellent and convenient mechanical strainers, are truly a hotbed for the lower forms of organic life.

The water is passed through the materials mostly downwards, sometimes upwards, or laterally. There are, of course, advantages and disadvantages incidental to each of these methods, but I believe that, by downward filtration, under otherwise like conditions, the most perfect purification is effected. The water, in passing through a granular material, upwards or laterally, has a tendency to force a passage through certain channels, wherever it finds the least resistance, without being uniformly disseminated through the material. Another defect of upward filtration is that the deposit of any filth, which mostly collects where the water enters the material, is excluded from view, and even largely from our sense of smell, instead of being exposed and giving us warning. Downward filtration, whilst free from these disadvantages, renders filtering materials liable to choke, owing to their natural tendency to follow the course of the water.

A filter ought to yield as much water, in a given time, as can be efficiently purified by the material, necessitating some arrangements for accurately regulating the flow of water. This arrangement ought, preferably, to be independent from any compression of the filtering medium, as, by simple compression, a satisfactory regulation cannot practically be obtained, and should it even be obtained in the first instance, as the yield necessarily decreases at once as soon as any suspended matter is deposited from the water between the pores of the material.

The construction of domestic filters would, nevertheless, be comparatively easy, could one always depend upon a little common sense in their use. But it is necessary to guard, as far as possible, against ignorance and mischief, even at the risk of complication. A point frequently disregarded by the user is that portable filters should be paced in a cool locality, free from any vitiated air, and the filter taps ought to be situated as conveniently as possible, so as to encourage the use of filtered in preference to unfiltered water. If the unfiltered water supplying the filter be stored in cisterns, they should be kept clean, and have no connection with water-closets or drains.

These are the main points which have guided me in designing the different forms of spongy iron filters. The ordinary portable domestic filter consists of an inner, or spongy iron, vessel, resting in an outer case. The latter holds the "prepared sand," the regulator arrangement and the receptacle for filtered water. The unfiltered water is, in this form of filter, mostly supplied from a bottle, which is inverted into the upper part of the inner vessel. After passing through the body of spongy iron, the water ascends through an overflow pipe. The object of this is to keep the spongy iron, when once wet, constantly under water, as otherwise, if alternately exposed to air and water, it is too rapidly oxidized.

On leaving the inner vessel the water contains a minute trace of iron in solution, as carbonate or ferrous hydrate, which is separated by the prepared sand underneath. This consists generally of three layers, namely, commencing from the top, of pyrolusite, sand, and gravel. The former oxidizes the protocompounds of iron, rendering them insoluble, when they are mechanically retained by the sand underneath. Pyrolusite also has an oxidizing action upon ammonia, converting it more or less into nitric acid.

The regulator arrangement is underneath the perforated bottom, on which the prepared sand rests. It consists of a tin tube, open at the inner and closed by screw caps at the outer end. The tube is cemented water-tight into the outer case, and a solid partition under the perforated bottom referred to. It is provided

with a perforation in its side, which forms the only communication between the upper part of the filter and the receptacle for filtered water. The flow of water is thus controlled by the size of such perforation. Should the perforation become choked, a wire brush may be introduced, after removing the screw cap and the tube cleaned. Thus, although the user has no access to the perforation allowing of his tampering with it, he has free access for cleaning. Another advantage of the regulator arrangement, is that, when first starting a filter, the materials may be rapidly washed without soiling the receptacle for filtered water. This is done by unscrewing the screw cap, when the water passes out through the outer opening of the tube, and not through the lateral perforation.

Various modifications had, of course, to be introduced into the construction of spongy iron filters, to suit a variety of requirements. Thus, when filters are supplied by a ball-cock from a constant supply, or from a cistern of sufficient capacity, the inner vessel is dispensed with, as the ball-cock secures the spongy iron remaining covered with water. This renders filters simpler and cheaper; and I incidentally remark that on this principle the larger sizes of filters, beyond portable domestic filters, are frequently constructed.

As the action of spongy iron is dependent upon its remaining covered with water, whilst the materials which are employed in perhaps all other filters lose their purifying action very soon, unless they are run dry from time to time, so as to expose them to the air, the former is peculiarly suited for cistern filters.

Cistern filters are frequently constructed with a top screwed on to the filter case by means of a flange and bolts, a U-shaped pipe passing down from this top to near the bottom of the cistern. This tube sometimes supplies the unfiltered water, or in some filters carries off the filtered water, when upward filtration is employed. This plan is defective, because it practically gives no access to the materials; and unless the top is jointed perfectly tight, the unfiltered water, with upward filtration, may be sucked in through the joint, without passing at all through the materials. This I remedied by loosely surrounding the filter case with a cylindrical mantle of zinc, which is closed at its top and open at the bottom. Supposing the filter case to be covered with water, and the mantle placed over the case, an air valve is then opened in the top of the mantle, when the air escapes, being replaced by water. After screwing the valve on again, the filter is supplied with water by the syphon action taking place between the mantle and filter case and the column of filtered water, which passes down from the bottom of the filter to the lower parts of the building. These filters are supplied with a regulator arrangement on the same principle as ordinary domestic filters. The washing of materials, on starting a filter, is easily accomplished by reversing two stop-cocks, one leading to the regulator, the other to a waste-pipe.

Another form of filter has been specially adapted for the use on board ships, the splashing of water, or shifting of the materials, consequent to the rolling of the ship, being prevented by suitable arrangements.

For the requirements in India and other colonies, a filter had to be constructed combining lightness, easy and safe packing, easy management and cheapness. In this there is no inner vessel, the spongy iron being kept covered with water by the joint action of two tin tubes, one sliding loosely over the other. The outer tube reaches from the top of the filter to a well with perforated sides, which rests on a watertight partition on the top of the receptacle for filtered water. The inner tube is closed at its base, reaching from the top of the spongy iron to some distance below the partition, through the center of which it passes. Within the receptacle for filtered water this tube is provided with a regulator similar to the one in the ordinary domestic filter. Thus the water is made to pass through the filtering materials, which rest on the water-tight partition, and the well enters the latter, ascends between the two tubes, and descends through the inner tube, whence it passes through the regulator opening to the receptacle for filtered water. A perforated lid on the top of the materials is arranged to be tied down during transport, to prevent shifting of the contents.

Permit me now to explain briefly what spongy iron is, and to make a few suggestions as to its probable action as a purifier of water.

Spongy iron is metallic iron, which has been reduced from some oxide of iron without melting the product. I have tried various arrangements for the production of spongy iron, including the Siemens' revolving steel furnace, and believe that a reverberatory furnace of suitable construction is best adapted to the purpose. The weight of spongy iron is about 1 cwt. per cubic foot, or one quarter of that of ordinary iron which has been fused. Its more powerful purifying action, as compared with ordinary melted iron, is largely based on the fine state of division. But if we bear in mind certain properties of spongy platinum, we can easily understand that the difference is not solely due to the physical condition of the spongy material, which may have affinities differing from those of ordinary iron. This is at once indicated by its property of decomposing water without the presence of an acid. Spongy iron also reduces nitrates and the carbonaceous and nitrogenous organic matter. Whilst it thus appears to have essentially a reducing action, there are also indications of an oxidizing process. Thus it appears that, under certain conditions, perhaps under the influence of some oxide, resulting from the gradual oxidation of the metallic iron, the ammonia may disappear entirely, being probably converted into nitric acid.

I need not explain to the members of the Chemical Section, that spongy iron is most energetic in precipitating any lead or copper, but even to chemists it is a remarkable fact, that it should reduce the temporary hardness of water very considerably, and the permanent hardness slightly. I cannot offer any explanation of the latter reaction, but the former, the reduction of the temporary hardness, is probably due to the affinity of the first product of oxidation, or ferrous hydrate, for the carbon anhydride, which is the solvent of the calcic carbonate. Ferrous carbonate is formed, and the calcic carbonate precipitated. From some reports, we shall presently see that this action was found to continue equally energetic for upwards of a year.

I have frequently been asked the question, what becomes of the organic impurities when filtering water through spongy iron. The reactions are of a complicated nature, and, up to the present moment, I can hardly give more than a few hints about them.

In two successive papers, one read before the Royal Society last year, the other recently, I have referred to a gas which I observed within the bulk of spongy iron, after it had been in use for some time. It is sometimes explosive, sometimes not. When ordinary water, such as that supplied by the New River Company, had been passed through a filter for several months, I found this gas to contain a hydro-carbon. On the contrary, when leaving spongy iron in contact with distilled water for an equal length of time, I failed to detect either carbon or hydrogen in the gas. This apparently demonstrates that the carbon in the former case was a product of the decomposition of organic matter.

It is likely that the nitrogen is, in the first instance at least, more or less converted into ammonia by filtration through spongy iron, but as ammonia is unquestionably at the same time produced in several other ways, I do not at present see how to furnish an experimental proof of that hypothesis.

Whether the ferrous hydrate formed by oxidation of the metallic iron has any decomposing action upon organic matter, is a question which I have not hitherto succeeded in answering. The final product of the oxidation is of course ferric hydrate. We know the destructive action of rust stains upon even such indestructible organic matter as linen and cotton fibres. It was, therefore, to be expected, that ferric hydrate should take an active part in the separation of organic matter from water. This led to the following experiments.

A glass bottle, tabulated at its base, was internally coated with a film of ferric hydrate, by filtering water through spongy iron, and then passing it into the bottle without previously separating the iron in solution. As soon as the bottle was nearly full, it was again emptied by a syphon arrangement, the soluble iron being thus oxidized and precipitated at the sides of the bottle. This was repeated until a sufficient deposit had been

obtained, showing the characteristic appearance of ferric hydrate. The bottle thus prepared, after being filled with hay infusion, was stoppered, and left to stand for a couple of months, when the color of the film gradually darkened. The bottle was then emptied, rinsed with water, and left exposed to the air. After about a fortnight, the coating almost regained its original yellowish-brown tint. It is thus evident that part of the oxygen had, in the first instance, been transferred from the ferric hydrate to the organic matter of the hay infusion. As any action would be much more energetic in the nascent state of the ferric compound, it became of interest to study more closely the re-actions which take place when passing water through the spongy material.

A tabulated glass vessel was filled with spongy iron. On allowing the water to pass through the vessel continuously for a few days, each granule appeared coated with ferric hydrate. However, on stopping the passage of the water, the color of the material which remained covered with water soon became darker, having after a few days, almost its original appearance. I explain this by a reduction of the coating of ferric hydrate, by agency of the kernel of metallic iron in each granule, the product being some lower oxide, which in its turn is readily re-oxidized to ferric hydrate by the oxygen dissolved in water. Thus the spongy iron acts indirectly as the vehicle for conveying the atmospheric oxygen to organic matter and this continues for a long time, as on the very top I found still a considerable proportion of metallic iron, after passing water continuously through spongy iron for upwards of ten months. Thus there are reducing and oxidizing agencies constantly at work in the spongy iron filter, and the several oxides of iron are present in their nascent state.

In entering upon the chemical evidence of the efficiency of those agents which are employed or proposed as purifiers of water, I regret that there should be so little conclusive evidence concerning them, excepting as to animal charcoal and spongy iron. Whilst I cannot hesitate to lay before you the evidence of disinterested authorities, I am naturally reluctant to refer to my own experience in judging of the merits of other materials than spongy iron. There was lately a chance of enlarging our knowledge on this subject, when the Sanitary Institute of Great Britain arranged for a competitive examination of domestic filters in connection with their exhibition at Leamington. Unfortunately, only a few of those invited thought fit to submit their filters to the trial, those represented comprising animal charcoal, the peculiar shale which is employed in some filters, and spongy iron. The committee appointed by the institute to test the purifying power and other merits of the several filters consisted of Dr. Bostock Hill, of Birmingham, county analyst; Dr. George Wilson, of Leamington medical officer of health: and Professor Cameron, of Dublin. You are probably aware that the award "for general excellence" of the Institute's medal was made to the spongy iron filter.

Important evidence on the same subject, though also incomplete, owing to the unwillingness of most manufacturers to submit their filters, is to be found in the Sixth Report of the Rivers Pollution Commission, "On the Domestic Water Supply of Great Britain." There we find the result of fifteen pairs of analyses of Thames water, before and after filtration through spongy iron, the testing being repeated about every fortnight. On comparing the average result of the two last pairs of samples with that of all samples, we find that, after the filter had been in constant action for upwards of eight months, the reduction of the important nitrogenous organic matter and of the hardness was still continuing.

I may take it for granted that the conclusions which have been drawn in the report from these analyses are known to you; they would, without doubt, have been still more satisfactory had not the spongy iron filter experimented upon been one of the very first ever made. Thus, it was of a somewhat crude construction, not provided with the regulator which has now become a feature of the filter: thus I account for a certain irregularity in the analytical results.

Now, in the same report, there is also exhaustive evidence as to the merits of animal charcoal as a purifier of water. It is demonstrated, and I think we all

are aware of this fact, that fresh animal charcoal removes not only a large proportion of the organic impurity, but also of the mineral matter. However, the report tells us the reduction of the hardness ceases in about a fortnight, the removal of organic matter continuing even after six months, though to a much less extent especially if the filter be much used. For this reason it was found necessary to renew the charcoal every six months, when used for the filtration of the comparatively pure water of the New River Company; whilst the water which is supplied from the Thames requires the renewal of the charcoal every three months. Unless this be done, we are told that myriads of minute worms are developed in the material, passing out with the filtered water. This statement sufficiently explains the final conclusion, but the property of animal charcoal of favoring the growth of the low forms of organic life is a serious draw back to its use, as a filtering medium for potable waters.

The chemical part of this evidence is more than corroborated by Mr. Byrne's experiments. He stated, in a paper read before the Institution of Civil Engineers in 1867, that on passing 12 gallons of moderately impure water through animal charcoal, over 55 per cent. of the organic matters were removed from the first gallon, but that this declined so rapidly that, at the eighth gallon, organic matter was given back to the water. In the debate on Mr. Byrne's paper, Mr. Chapman stated that he actually recovered from the charcoal the amount of organic matter which had been previously removed by it from a water. If we compare these statements with others which are more favorable to charcoal, we must, I think, conclude that under certain conditions, which are as yet not thoroughly understood, it appears capable of giving more satisfactory results. Probably this depends largely upon the thorough burning, without alteration, of the physical structure.

But, granted that there are no remains of half charred flesh or fat in the charcoal filter; that all organic matter has been destroyed by burning; even then we can explain the physiological results referred to in the report, namely, the liability of favoring the growth of the low forms of organic life. An intimate connection appears to exist between these and phosphorus, as is clearly demonstrated by the microscopic water test which has been proposed by Mr. Heisch. If a minute quantity of cane sugar be added to ordinary water, low organisms are developed in such enormous numbers, as to cause, in about twenty-four hours, an opalescence, or milkiness. Dr. Frankland has demonstrated that this is wholly or partially due to the minute trace of phosphorus contained in sugar, as he obtained a similar result by adding a variety of compounds of phosphorus instead of sugar. Is it then astonishing that animal charcoal, containing some seventy-five per cent. of calcic phosphate, which is by no means insoluble in water, should produce a like effect?

If I have succeeded in demonstrating that fermenting organic matter is amongst the most objectionable impurities in water, the preceding suggestions are worth our fullest attention, as the milkiness produced in water by sugar is unquestionably due to fermentation. But the objection to the use of animal charcoal as a filtering medium for portable water becomes still more serious, if we assume that some of the most disastrous epidemic disases are produced by low forms of organic life. Can we, in this case, *á priori*, maintain, that their growth may not also be favored by animal charcoal? Chemical analysis is incompetent to deal with this question, for the living matter in water is by weight always insignificant, as compared with the dead organic matter. Analysis may, therefore, show, after filtration, a considerable reduction of the total organic matter, and yet those living bodies may have enormously increased.

May I, in further support of this important point, refer you to my researches, which you will find in the proceedings of the Royal Society? With a view of testing the purifying action of spongy iron, physiologically, I left meat in contact for many months with ordinary water, or even hay infusion, both having been filtered through spongy iron. The meat remained fresh throughout, if no putrefactive agents had access to it, excepting those that might have passed with the water or hay infusion through

the filtering medium. Putrefactive agents were, therefore, absent from the filtered liquids. But on filtering the same kind of water as before, under otherwise precisely like conditions, through animal charcoal, the meat was putrid after a short time. It would of course have been useless to extend the latter experiment to hay infusion.

From these results we may draw important practical conclusions. Fermentation or putrefaction are some of the most powerful agents in destroying organic matter by converting it into a number of gaseous and other constituents. If such fermentation be constantly at work within a filtering medium, we can understand what becomes of the organic matter, should it even be only mechanically retained in a filter. But this is different in the spongy iron filter, looking at the preceding results. Putrefaction being unable to effect the elimination of organic impurities, they must either accumulate or be got rid of by some such chemical agency as before suggested. A constant accumulation would necessarily soon result in a contamination of the filtered water, the latter taking up organic matter from the filtering medium, as we found it stated in the case of animal charcoal. This being contrary to all evidence, we must conclude that no such accumulation takes place, but that the organic impurities are destroyed and rendered innocuous in the spongy iron filter, by at least as powerful chemical agents as fermentation and putrefaction.

You are probably acquainted with the three reports in the Registrar General's returns for 1876, 1877, and 1878, on the spongy iron filter, and I might pass them over, did I not wish to draw your attention to the interesting result recorded in the report for 1877, that even in times of flood, when the Thames was unusually loaded with organic impurities of the most disgusting origin, its water was, after filtration through spongy iron, purified to such an extent as to surpass the Kent water, which, from its freedom from organic contamination, is justly considered the standard of purity. The organic carbon in the filtered Thames water was .038 in 100,000 parts, that in the Kent water .048. Both were equally free from organic nitrogen, but the hardness of the filtered Thames water was less than one-third that of the Kent water. The filter had previously been in use for more than a year without change of materials. The ammonia in the filtered water was increased to .010. Referring to the correspondence on this subject in the early numbers of the *Chemical News* during the present year, I maintain, that we cannot draw from the presence of ammonia in such filtered water any inference, which might be more or less justified when analyzing a natural water that has not undergone any such artificial treatment.

By direction of the Under Secretary for War, a trial of filters was commenced at the Army Medical School, Netley, by the late Dr. Parkes, and completed about two years later by Dr. de Chaumont. It was found that of all filters experimented upon, the spongy iron filter alone yielded water in which no living or moving organisms could be detected under the microscope.

A report strongly recommending spongy iron has also been recently made to the Prussian War Minister by the military authorities at Coblenz. It is based upon experience with a large filter during an epidemic of typhoid amongst the garrison. A copy of the report has been promised to me, but as yet I have not received it.

Lastly, a report was made at the Somerset House laboratory, by request of the Secretary for India, which is throughout in favor of the spongy-iron filter.

I have devoted so much time to domestic purification of water, because, as a rule, it is more effective than that on a large scale before delivery of the water to the consumer. This hardly requires an explanation. Look at our city. Its daily requirement of water, in round figures, is 120 million gallons. Such an enormous quantity is not easily dealt with, moreover, only a small proportion is used for drinking and cooking. This consideration has lately led to the proposal of two distinct water supplies, one for drinking and cooking, and another for general use. We then might either have derived the former supply from unexceptionally pure sources, or we might have bestowed so much more care and expense upon the purification

of the potable water. But although this apparently would have been a satisfactory solution of the question, I am afraid it is fraught with great difficulties indeed.

If that scheme had ever been carried out, the present water supply would, almost, as a matter of necessity, have been neglected, as its purity for flushing and the like is of no great consequence. The quantity of water for drinking and cooking alloted to each consumer by the provisions of the scheme was very liberal; but suppose the supply of pure water had ever failed, what would have been the consequence? Again, I do not see how any householder could possibly have been prevented from using three or four times the quantity of pure water he was entitled to. The result must have been inevitably an insufficiency elsewhere. Now, in these cases, and if by negligence or obstinacy of servants the impure water were used for drinking, it would have been a most serious matter had our present supply deteriorated.

In view of the difficulty of purifying the whole water supply, or of branching off a separate supply for internal use, we would at once dismiss purification on the large scale as undesirable, and confine ourselves to domestic filtration, if not there again we found most serious objections. We cannot expect, for the present at least, to reach with domestic filtration the poorer classes and we have not only an interest in their welfare as our "neighbors," but we are personally interested in it. However careful we may be to exclude disease from our houses, by providing a wholesome water, disease may be spread to them from the houses of the poor.

This leads me to a practical suggestion. I take it for granted that in London, and the same holds good in many other localities, careful filtration through sand is sufficient almost throughout the year. Why, then, should not additional means of purification, say through spongy iron, or any other medium that may be found preferable, be held in readiness, to be used only in emergencies, such as floods, or during periods of epidemics? The same spongy iron might thus be made to last at least five or six times longer than when continuously used, and the working expenses would be so considerably reduced as to become insignificant. I believe, that, with an efficient supervision of the water supply, this proposal might work very well, offering all reasonable guarantees.

A water which has never been polluted would certainly be preferable to one which, after contamination, is re-purified. But where is, with rare exceptions, water to be found which has never been polluted? Deep-well waters and even spring waters are unquestionably more or less supplied by polluted surface water, which is purified by natural filtration. If analysis, if the microscope, prove that artificial filtration is equally or even more effective, if the physiological character of both waters should prove the same, we may, I think, as safely rely upon artificial as upon natural filtration, and more so upon the former, as the naturally purified water may fail, whilst artificial filtration may be carried out to almost any extent.

GAS AS FUEL.

By M. M. PATTISON MUIR.

From "Nature."

Attempts have been made from time to time to use gas as a means for heating; these attempts have more frequently failed than succeeded, chiefly by reason of the mechanical difficulties to be overcome.

It is pretty generally agreed that, on account of the ease with which the supply of a gaseous fuel can be regulated, the completeness with which such a fuel can be burned, the comparative readiness with which cleanliness can be maintained while using this fuel, and by reason of its high heating power, and for other reasons, gaseous fuel is to be much preferred to fuel in the solid form.

The most perfect gas for heating purposes would be that, the constituents of

which should be all combustible, should be possessed of high thermal powers, and should produce, on burning, compounds of small specific heat. No gas which has yet been produced for use as fuel completely fulfills these conditions.

Common coal-gas contains such non-combustible bodies as carbon dioxide and nitrogen, and among the products of its combustion is water, a body of large specific heat, and also requiring a considerable amount of heat to convert it into vapor. The complete combustion of coal gas also necessitates a comparatively large supply of air, and this, again, involves special mechanical appliances. Nevertheless, coal-gas has been proved to be, for certain purposes, a cheaper, more effective, and more easily managed fuel than coal, wood, or other forms of solid heat-giving material.

That steam is decomposed by hot carbon with the production of a gaseous mixture of considerable heating powers, has long been known, and several attempts have been made to utilize the products of this decomposition. These attempts have met with no great success on account of the cost of the plant required to work the manufacture and of the difficulties of the process. Long-continued experiments have, however, been carried on, and it would appear from a paper recently communicated to the Society of Arts by Mr. S. W. Davies, that these experiments have been crowned with a very fair measure of success.

The great difficulty was a mechanical one: it has been very simply overcome. Superheated steam is produced in a coil placed within a cylinder and is driven by its own tension in the form of a jet into the lower part of an anthracite fire. The jet of steam carries with it air sufficient to actively maintain the combustion of the anthracite; the gases issue at the top of the apparatus and pass into the mains. The fire is fed from the top by an arrangement which allows of the process being continuous. Water is forced into the coil under a pressure varying from fifteen lbs. to forty lbs. on the square inch. The whole apparatus is compact and simple.

The products of the decomposition of steam by hot carbon are mainly hydrogen and carbon monoxide; traces of marsh gas are also formed. Could these gases be produced free from admixed non-combustible bodies we should have a gas of very high heating powers. But the temperature of the glowing carbon must be maintained by the introduction of oxygen, that is, in practice, by the introduction of air. The problem how to introduce air sufficient to keep up vigorous combustion, and at the same time to maintain the decomposition of the steam, appears to have been satisfactorily solved; but the introduction of air means a lowering of the heating power of the gas produced, inasmuch as four volumes of nitrogen are brought in along with every volume of oxygen supplied. By passing the gas through a series of vessels containing hot carbon the nitrogen may be very much diminished in amount, and the heating power of the gas proportionally increased.

The gas produced by the decomposition of steam by hot carbon always contains traces of carbon dioxide which is non-combustible; the amount of this compound may, however, be reduced to three or four per cent. by regulating the depth of the layer of hot carbon through which the gases pass, and by maintaining the temperature of that carbon at a high point. But the maintenance of a high temperature throughout a mass of carbon can be accomplished, under the conditions of the manufacture, only by introducing a rapid current of air, which again means a dilution of the gas produced.

If, therefore, means could be found for feeding the anthracite fire with oxygen, a gas of very high heating power might be produced. A supply of oxygen at a cheap rate is a great desideratum; the gas exists in practically unlimited quantity in the atmosphere, but an easy and successful method for separating it from the nitrogen with which it is there mixed is still only hoped for by the chemical manufacturer. Were a supply of oxygen forthcoming, mechanical difficulties would present themselves before it could be utilized in the production of "water gas." The introduction of too small an amount of oxygen would mean the non-decomposition of the whole of the steam and the cessation of the combustion of the anthracite; the introduction of too much oxygen would mean the produc-

tion of carbon dioxide in considerable quantity. But by regulating the size of the steam jet and of the blast-pipe, these difficulties might probably be overcome.

As the gas is now produced all danger of explosion is removed.

The heating effect of the gas as at present manufactured is about one-fifth that of ordinary coal-gas, for equal volumes; but the cost of the gas is so much less than that of coal-gas, that a given amount of heating work may be done—according to the figures given in the paper referred to—by using the new gas, with a saving of from one-third to two-thirds of the expenditure which would be involved were coal-gas employed.

Although the new gas is not perfectly adapted for the purposes for which it is to be used, yet there can be little doubt that we are now a step, and a very considerable step, nearer the final solution of the problem. Doubtless improved furnaces, and improved apparatus generally for burning the improved fuel will be introduced.

The production of a cheap gaseous form of fuel is a great gain; so also is the invention of a means whereby the large stores of anthracite coal in this and other countries can be utilized.

Of all the forms of carbon experimented with in the production of the new gas, anthracite was found the best. Anthracite is difficult to burn; the ordinary forms of furnace do not admit of such a complete oxidation as is required in order to maintain the combustion of anthracite. But the blast of air carried into the gas generator of the water-gas apparatus by the steam jet insures the presence of a large quantity of oxygen, and therefore the combustion of the anthracite. Whether a simpler means could not be adopted for the combustion of anthracite is a question worthy of consideration. That a steam jet can be thrown into an ordinary furnace charged with anthracite, and the combustion of the coal be thereby insured, has been shown to be possible. Nevertheless, the production of combustible gas from the anthracite is to be preferred, for many reasons, to the consumption of the solid fuel.

The fact that we shall soon probably be in a position to make use of our stores of anthracite, is one of very considerable importance from an economic point of view. In possessing large quantities of anthracite we possess a valuable commodity, but if we cannot realize a use for that commodity it ceases to be a source of wealth to us.

Further, large quantities of anthracite are known to exist in some of the British Colonies and in the United States; the utilization of these would mean an increase in the commercial enterprises owned by Englishmen abroad, or supported by English capital; it would also probably imply an increase in the tonnage of shipping, and would thus tend to increase our "international wealth."

Whether it be regarded from the point of view of the chemist, or of the economist, the introduction of a cheap gaseous fuel manufactured from anthracite, marks a point of no little importance in the advance of manufacturing industries.

The experiments detailed in the paper by Mr. Davies show that the new gas is especially adapted for use in cooking operations in large private establishments, in clubs, hotels, barracks, &c. It is known that cooking can be more cheaply and more rationally conducted with the aid of gaseous than of solid fuel; if the new fuel does all that it promises to do, judging from the actual trials already made, its introduction will be welcomed by the artistic cook no less than by the scientific chemist, and by the political economist.

Good strong blown glass tumblers are being delivered into English ports from America for 8d. per dozen, and good hexagonal and octagonal cut Dutch tumblers for 4s. 8d. per dozen. The above fact relating to importation from the United States, from whence but recently nothing of the kind was exported, is illustrative of the keen competition in manufactures generally, and in particular shows the necessity for the abolition of the English glass blowers practice of working but four days per week, a practice maintained by the glass blowers' guild, and one which prevents the continuous operation of the costly furnaces and plant in a glass works. A smaller profit on most English goods will have to be accepted in the near future.

STEAM ENGINE ECONOMY—A UNIFORM BASIS FOR COMPARISON.

By CHARLES E. EMERY, M. E.

From the Transactions of the American Society of Civil Engineers, March, 1878.

In writing a general report on the exhibits referred to the Judges of Group XX, Centennial Exhibition, the writer compared the facts available in regard to the economy of steam engines of various kinds, on the uniform basis that the boiler is capable of absorbing 10,000 heat units per pound of coal consumed. This corresponds to an evaporation of 8.99 pounds of water at 80 pounds pressure, 9.03 pounds at 60 pounds pressure, or 9.08 pounds at 40 pounds pressure from a temperature of 100° in each case. This evaporation is higher than is usually obtained, but has been so much exceeded in practice* that it is not considered too high for a basis of comparison. The basis moreover enables the duty of pumping engines and other steam machinery to be ascertained and expressed in a very ready and convenient manner. Ten thousand heat units per pound of coal is equivalent to one million heat units per 100 pounds of coal and as the duty of pumping engines is conventionally expressed in millions of foot pounds per 100 pounds of coal it follows on the basis presented that *the number of foot pounds per heat unit represents also the number of millions of foot pounds duty per* 100 *pounds of coal.* The performance of all kinds of steam engines may be readily compared on this basis. The simplest application is in testing vacuum pumps, the duty of which may be readily ascertained by noting the height of lift, and the initial and final temperatures of the water lifted. All the heat of the steam not expended in work enters the water, and the work performed lifts the same water. The difference in temperature gives very nearly the number of heat-units imparted to each pound of water lifted, and each pound of water so heated is lifted a certain number of feet high, so the result may be expressed readily in foot-pounds per heat-unit, which, as before stated, equals also, on the basis presented, the number of millions of foot-pounds duty for 100 pounds of coal. For ordinary comparisons the number of millions duty equals the lift, divided by the difference between the initial and final temperatures of the water. For more accurate computations, the divisor should be increased by the number of heat-units expended for work per pound of water lifted, which equals the height divided by 772. The height preferably should be calculated from the indications of a pressure-gauge at the bottom of the discharge-pipe, so as to include frictional resistances. If D = duty in foot-pounds per 100 pounds of coal, H = the height of lift per gauge, and t and T = the initial and final temperatures respectively, then

$$D=\frac{1,000,000\ H}{T-t+.0013\ H.}$$

Arrangements have been made by the writer to use the same basis in testing pumping-engines, by discharging water from the hot well into the suction of the main pumps, and noting with delicate thermometers the resulting increase of temperature of the water lifted

A vacuum-pump tested by the writer in 1871 gave a duty, on the above basis, of $4\frac{7}{10}$ millions; one tested by Mr. J. F. Flagg, at the Cincinnati Exhibition in 1875, reduced to the same basis, gave a maximum duty of $3\frac{25}{100}$ millions. Several vacuum and steam pumps tested on this basis, at the suggestion of the writer about two years since, gave duties reported as high as 10,000,000 to 11,000,000, the very small steam-pumps doing no better apparently than the vacuum-pumps, which is by no means surprising. Elaborate experiments made with steam-pumps at the American Institute Exhibition of 1867* showed that average-sized steam-pumps do not, on the average, utilize more than 50 per cent. of the indicated power in the steam-cylinders,

* See examples at page 75 of the report referred to.

* See Report of Messrs. Holmes, Selden, and Emery, Judges, etc., *Transactions American Institute*, 1867–68.

the remainder being absorbed in the friction of the engine, but more particularly in the passage of the water through the pump. Again, all ordinary steam-pumps for miscellaneous uses require that the steam-cylinder shall have 3 to 4 times the area of the water-cylinder to give sufficient power when the steam is accidentally low; hence, as such pumps usually work against the atmospheric pressure, the net or effective pressure forms a small percentage of the total pressure, which, with the large extent of radiating surface exposed and the total absence of expansion, makes the expenditure of steam very large. One pump tested by the writer required 120 pounds weight of steam per indicated horse-power per hour, and it is believed that the cost will rarely fall below 60 pounds; and as only 50 per cent. of the indicated power is utilized, it may be safely stated that ordinary steam-pumps rarely require less than 120 pounds of steam per hour for each horse-power utilized in raising water, equivalent to a duty of only 15,000,000 foot pounds per 100 pounds of coal on the same basis adopted for the vacuum-pumps. With larger steam-pumps, particularly when they are proportioned for the work to be done, the duty will be materially increased.

Ten thousand heat units per pound of coal represent an ultimate efficiency of only ($10,000 \times 100 \div 14,500$*$=$) 69 per cent. of the calorific value of anthracite coal, so that ordinarily more than ($100 - 69 =$) 31 per cent. of the heat in the fuel is carried to waste up the chimney. A still greater loss is, however, experienced in utilizing the steam for the purpose of work in the engine. The mechanical equivalent of one heat-unit is 772 foot-pounds, which, on the basis referred to above, corresponds to a duty of 772 millions of foot-pounds per 100 pounds of coal. The most economical steam-engines, for instance pumping-engines of approved types, utilize in the steam-cylinder only about 130 millions, on the same basis, equivalent to an ultimate efficiency of ($130 \times 100 \div 772 =$) 16.84 per cent. of the heat in the steam, and but ($16.84 \times .69 =$)11.62 per cent. of the calorific value of the fuel. The principal reason for this is that the exhaust steam necessarily carries to waste the heat required to maintain it in a vaporous state at the tension due to the back pressure. This, under the most favorable circumstances, forms the larger proportion of the total heat of the steam, and reduces the opportunities for securing economy within small limits compared with the theoretical limit, although the differences between the performances of different engines are great when compared one with another.*

Means for securing economy in steam-engines may be divided into two classes, viz., those of a mechanical nature and those which influence the thermal conditions. As to the first, the necessity of securing tight pistons and valves, ample area of cylinder passages, reduced clearances, etc., are well understood, also the incidental advantages due to a certain degree of compression. Those of the second class act to reduce the cylinder condensation, and include high speeds of revolution, steam superheating, steam-jacketing, and the compounding of engines. High speed of revolution (which does not necessarily imply high piston speed, as generally understood) secures economy, by reducing the time in which the transfers of heat to and from the steam and inclosing walls must take place.†

Superheating the steam has experimentally proved effective for moderate rates of expansion, in which the original

* The calorific value of anthracite coal is usually considered to be that of the carbon element or 14500 heat-units.

* In view of discussions in progress at the date of writing on the proper details of a theoretically perfect steam-engine, it is proper to mention that in the year 1868 the writer designed and partially constructed a non-exhausting experimental engine in which the steam, after expansion in the cylinder, was to be circulated through another vessel, to withdraw the water due to the performance of work; the dry steam was then to be returned to the cylinder and compressed, which it was expected would require less power than the expansion would furnish, and sufficient steam only be received from the boiler to supply that condensed for work. A demonstration of the correctness of the principle only was intended, the power expected being so small that the experimental engine was to be connected to another to keep it in motion. Before the apparatus was completed the funds were diverted to objects of greater immediate necessity, and the subject is mentioned only as indicating the general principle upon which a theoretically perfect steam-engine may be constructed. See description of the apparatus in article on the "Theoretical Steam-Engine," *Scientific American* Supplement, Aug. 18, 1877. See also Prof. Thurston's calculations on a similar subject in *Journal of the Franklin Institute*, Oct., Nov., and Dec., 1877.

† The value of this saving was determined by the writer for the Novelty Iron Works, Mr. Horatio Allen, President, in the year 1868, and embodied in a series of tables showing the relative power and economy of different sizes of steam-engines, which tables were afterwards published by Prof. W. P. Trowbridge, the former Vice-President of the company.

temperature required to maintain the gaseous condition of the steam to the point of release was not too high to prevent proper lubrication. Mr. Geo. P. Dixwell, of Boston, Massachusetts, has applied a thermometer to a steam cylinder, by inspection of which it is possible to regulate the temperature so as to prevent injury to the metal surfaces. The great difficulty is, however, to secure a permanent and reliable superheating apparatus. Steam-jacketing has to a limited extent advantages of the same kind as superheating, and involves no serious difficulties in management. The jackets are most effective on long cylinders of small diameter. In experiments with United States revenue steamers, hereinafter mentioned, the economy of a steam-jacket on a comparatively short cylinder was found to be eleven to twelve per cent.

Compound engines, in addition to advantages of a mechanical nature, in better distributing the strains and rendering more uniform the rotative efforts, serve also to reduce cylinder condensation by the distribution of the differences of temperature between two cylinders. The radiation to and from the steam and its inclosing walls increases more rapidly than the difference in temperature, so that the aggregate loss, when the difference of temperature is divided between two cylinders, is less than when it all occurs in a single cylinder*. Moreover, the heat imparted to the exhaust steam by the metal of the first cylinder is available for work in the second, and the low-pressure piston acts as a screen between the high temperature in the small cylinder and the low temperature in the condenser.

It is still strenuously denied by many that greater economy can be secured with a compound engine than with a long-stroke single engine using the same steam pressure. There are coasting steamers of similar size running regularly in the United States using both types of engine, with, it is claimed, substantially the same results; but the boilers for the single engines are evidently the more economical, making an accurate comparison impossible. Strictly comparative experiments have, however, been made by Chief Engineer C. H. Loring, U.S.N., and the writer with engines of different kinds in the steamers of the United States Revenue Marine, and by the writer with some of those of the United States Coast Survey.*

The revenue steamers were of the same size and the boilers very nearly identical. In one steamer was a compound engine with steam-jacketed cylinders; in another, a long-stroke, high-pressure condensing engine (cylinder not jacketed); in another, an ordinary low-pressure engine (cylinder not jacketed); and in still another, a high-pressure condensing engine with a jacketed cylinder. The compound engine showed a saving of 12 to 16 per cent. compared with the best performance of either single engine when operated at the same steam pressure. It is believed that substantially the same differences will be found in all cases when equally good engines of both types are compared. The performance of a short-stroke compound engine may be equaled or even excelled by that of a long-stroke single engine, on account simply of the difference in clearance spaces and the superior efficiency of the steam-jacket in the latter case, but by making the compound cylinders in the same form they should still show an advantage. In practice, the economy of marine compound engines is greater than above mentioned, for the reason that the high steam pressure is better maintained with them by the engineers than when single cylinders are used with high rates of expansion, causing difficulties in management.

The following table shows in line 1 the performance of one of the Leavitt compound beam pumping-engines, at Lawrence, Massachusetts, and in line 2 that of the engines of the *Rush*, one of the revenue steamers previously referred to :

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* See article by the writer in *American Artizan*, March 8th, 1871. See also this Magazine for May, 1871.

* See article by the writer on "Compound and Non-Compound Engines," *Transactions American Society of Civil Engineers*, vol. iii. p. 68, 1875; *Journal of the Franklin Institute*, Feb. and March, 1875; *Engineering* (London), Jan., Feb., and March, 1875; *Proceedings of Institution of Civil Engineers* (British), vol. xl. p. 292, and vol. xli. p. 296; also report of trial of United States revenue steamer Gallatin, *Journal of the Franklin Institute*, Feb., 1876, and vol. xxi., *Engineering*, 1876.

Number of Line.	Approximate Steam Pressure.	Ratio of Expansion.	Diameter of Small Cylinder.	Diameter of Large Cylinder.	Strokes of Pistons.	Revolutions per Minute.	Piston Speed.	Mean Pressure referred to Large Cylinder.	Indicated Horse-Power.	Water per Indicated Horse-Power per Hour.
			Inches.	Inches.	Inches.		Feet per Minute.	Pounds.		Pounds.
1	90	13.5	18	38	96	16.27	260.3	22.15	196.4	14.02
2	70	6.22	24	38	27	70.84	318.8	24.48	266.6	18.38

The comparison is very interesting. In both engines the larger cylinders are of the same diameter, but the difference in the duty for which the engines were designed required great differences in other proportions and in all the details of construction. In the pumping-engine for use on land there were no restrictions as to weight and space, so a comparatively long stroke could be employed and the connections made through a beam. The marine engine had, however, to be located in a small vessel, and was therefore directly connected and proportioned accordingly. Yet the long-stroke engine was run with so much expansion and at so slow a speed as to develop less power than the smaller one, and the latter was less economical, on account of the lower steam pressure and rate of expansion and the relatively greater proportion of waste room in the cylinder, incident to the necessary use of ordinary slide-valves. The engine of the *Rush* was, however, more economical than the ordinary stationary compound engines used for manufacturing purposes, as the latter, according to published reports in the engineering journals, require the evaporation of not less than twenty pounds of water for each indicated horse-power. The Lawrence engine contains all well-known means for securing maximum economy of steam, and it is probable that few if any engines are working with greater economy in respect to the indicated power. The performance is, however, much below that given by calculation when all the conditions are taken into consideration, other than the slight distortion of the theoretical indicator diagram found in practice and the important loss due to cylinder condensation.

In an engine using a total pressure of $(90+14.7=)$ 104.7 pounds, expanded 13.5 times in a cylinder, with clearances, etc., equal to .02 of the displacement, the calculated cost of one horse-power per hour, or 1,980,000 foot-pounds, should be only 8.12 pounds of water evaporated from the initial pressure, on the basis that the curve of expansion is hyperbolic, and that the consumption of steam equals the volume at the initial pressure required to fill the cylinder to the point of suppression, plus that condensed for the total work. With a pressure of 100 pounds above the atmosphere, and an expansion of twenty times, there should be required on same basis the evaporation of only 6.00 pounds of water per indicated horse-power per hour. It is probable that the practical results obtained with the latter pressure and expansion would be little or no better than those from the Lawrence engine, on account of the greater cylinder condensation due to the increased expansion.

The above-calculated performances, and the practical results obtained with engines and other steam machinery of various kinds, is shown in the accompanying table, in connection with the relative efficiencies obtained by considering the heat units in the steam and the calorific value of the fuel. The table and a portion of the above are from the report previously mentioned and the references are to pages therein :

	1	2	3	4	5	6	7	8
					Comparative Results on Basis that 10,000 Heat-Units are imparted to Water per Pound of Coal. See pp. 21 and 115.§ Calculations based on a Temperature of Feed of 100°.			
Number of Line for Reference.	Description.	Steam Pressure.	Ratio of Expansion.	Water evaporated per indicated Horse-Power per Hour.	Duty in Millions of Foot-Pounds, per Indicator, per 100 Pounds of Coal. Pages 21 and 115.§	Relative Efficiency, based on the Proportion utilized of the Total Heat of the Steam.	Relative Efficiency, based on the Proportion utilized of the Calorific Value of Anthracite Coal.	Net Effective Duty for Lifting Water, in Millions of Foot-Pounds, per 100 Pounds of Coal.
1	Calculated performance. Maximum	—	—	—	772.0	1.00	.690	
2	Calculated performance (see page 120)	100	20	6.005	295.2	.382	.264	
3	Calculated performance	90	13.5	8.122	218.6	.283	.195	
4	Lawrence compound beam pumping-engines	89.4	13.7	14.019	126.7	.164	.113	
5	U.S. Revenue steamer Rush,* compound engine	69.2	6.22	18.384	97.03	.126	.087	
6	U. S. Revenue steamer Gallatin,* vertical cylinder with steam-jacket	67.2	4.19	21.48	83.08	.108	.074	
7	U. S. Revenue steamer Dexter,* vertical cylinder without steam jacket	67.1	3.49	23.905	74.66	.097	.067	
8	U. S. Revenue steamer Dallas,* vertical cylinder without steam-jacket	32.0	3.13	26.945	66.91	.087	.060	
9	U. S. steamer Mackinaw,† inclined cylinder without steam-jacket	49.0	2.2	30.306	59.16	.077	.053	
10	U. S. steamer Mackinaw, steam superheated	52.0	3.2	22.725	78.83	.102	.070	
11	Non condensing engine, with governor cut off‡ (st. jacket)	81.7	5.0	25.482	69.81	.090	.062	
12	Non-condensing engines, regulated by throttle	—	—	—	30 to 45	.04 to .06	.03 to .04	
13	Pumping-engines							30 to 110
14	Steam-pumps. Large size proportioned for the work to be done							15 to 30
15	Steam pumps. Small sizes for ordinary uses. See page 22 §							8 to 15
16	Vacuum-pumps. See page 21 §							3 to 10
17	Injectors when used for lifting water not required to be heated. See page 96§							2 to 5

* See references in foot-note, page 119, and page 44 of this No.

† See vol. ii, Isherwood's *Experimental Researches in Steam Engineering*, pp. 77–116.

‡ *American Institute Reports*, 1869–70, 1870–71.

§ General Report of the Judges of Group XX, Philadelphia International Exhibition. Lippincott & Co., Phila.

ACCURATE NAVIGATION.

By Captain MILLER.

From "The Nautical Magazine."

There are many non-nautical critics, learned as well as unlearned, who take it for granted that navigation as a perfect science is always available to the navigator. They seem to think that under all circumstances he has simply to work out a few problems, which they suppose can be done at any time, and if done correctly and properly applied must necessarily lead to infallible results. Notwithstanding the apparent blunders, the numerous casualties, and the pile of evidence to the contrary, that continually come to light through our Courts of Inquiry, these persons comment as flippantly on any particular case of casualty as though there were no reason why a ship should not arrive at her destination as accurately as a railway train, which, starting from one end of the kingdom, runs up to its terminus at the other within a foot of the platform.

Unfortunately for the value of these comments, there are no rails laid over the seas, and until this is actually achieved ships will continue to deviate from straight courses. As Nature is said to abhor a vacuum, so ships in their courses seem to abhor being kept to perfectly straight lines. All that science does for the navigator is to aid him occasionally; occasionally, I say, because science in her attendance on him is very whimsical, being present only when her assistance is least required, and invariably being absent when her assistance is most needed. When, for example, the navigator has the full use of vision and can see everywhere around him, when through having the use of this vision there is no risk of his running his ship into danger, and navigating her is comparatively an easy process, then science, with her brightest smiles, is always present, ready to overwhelm him with the tender of her innumerable problems to verify his position. But when, having to run for some iron bound coast, the weather thickens for some days previous to his reaching it, and wind and sea press and heave the ship an unknown amount from her track, when all is thick, dark, and dreary, and vision altogether fails, when the ship may be said to be running through a sort of "valley of the shadow of death," where then is science with all her bright smiles and tenders of assistance? These are the times when the navigator most needs her presence, but these are the times when she always absents herself, and leaves no other assistance, to aid him in his most difficult and delicate work, than that assuming and guessing old pilot called "dead reckoning."

I wonder why our ancestors called this old pilot *dead*. He is certainly not yet dead, for we have him now piloting ships in these days. He still has sufficient life to undertake, in the absence of science, to pilot ships to their destination. He is, however, very old and very unsuitable for the times, his range of vision is far too small for these go-ahead days —he was always very near and weak-sighted at best, but he got on very well in his younger days with our ancestors, whose ships were slow, and *time* with them was no very great object. With them he had always ample time at his command, and he took great care to make every use of it, for when he could not see and became a little uncertain of his position, he would stop. Stopping in those days was neither a fault nor a danger, so he stopped for every shadow of a doubt. By this expedient he could easily keep what perceptions he possessed well in hand, but he cannot now resort to this expedient, the times will not admit of it. Speed, speed is the great demand of the age. He often therefore loses control, becomes bewildered, and leads ships with all on board frequently to disaster and death. If it was in this sense that our ancestors called him *dead*, it is an appropriate name for him, for his piloting leads so very often to fatal disaster. Nevertheless, this untrustworthy old pilot is all the assistance the navigator has to aid him whenever science hides her face, and unfortunately for our climate she does this for many days together, and far too often for the interests of life and property. Some-

times thick weather sets in 500 or 1000 miles to the westward of the Channel, and continues until the navigator either gropes his way to his destination, or adopts the "Westminster Abbey or Victory" principle; depends on dead reckoning, and runs for it regardless of consequences. Both of these principles have their followers, and the latter, strange to say, often succeeds, though there is no basis of certainty in the correctness of any of their calculations. Their figures and problems may indeed be perfect, but unfortunately "dead reckoning" is not simply a question of figures, it is made up also of a number of assumptions and guessings, none of which in thick weather can be checked.

In the first place, no helmsman can steer a course accurately; some steer much better than others, but the best cannot conn the ship as though she were rnnning on rails. The course is given to a quarter of a point, sometimes to a degree, and the seaman simply makes the best use he can of it. But much uncertainty surrounds even the best performance when the ship is running for land in and after continued thick weather, no matter how smooth the sea; and naturally in proportion as the sea is rough will this uncertainty be aggravated. The science of navigation, as yet, does not supply the navigator with any instrument that will register the amount of deviation from a straight course, made in consequence of defective steering, and the question therefore is, when the light of science is absent, and vision as a preventive to disaster useless, what margin of error is to be allowed for it, and which way, whether to the right or to the left? But science is absent, she does not answer this question; and as for "dead reckoning," he is too stupid to give it even a thought; in this case, as in all cases, excepting those for which he allows lee-way, he assumes that the course given to the helmsman is "made good," and all his calculations are based on this assumption.

Besides defective steering, science has left the navigator, in an iron ship, to find his way in thick weather as best he may, with a very defective compass. This is the case whether it be an uncompensated standard or one said to be adjusted. What a fraud on the understanding and practical experience of the navigator it is to say, because a number of magnets are screwed down to the deck round his compass, acting at cross purposes with each other, that therefore his compass is adjusted. In spite of any number of fixed magnets that can be placed round it, it is not adjusted. It is only a rude attempt at adjustment, and a very delusive one also.

But let us consider the value of the standard compass towards making an accurate course, as this is the one, doubtless, that the navigator will employ. Now the compass-card, with its magnetic needles, somewhat resembles the fly-wheel of machinery, with this difference, that, instead of being expected to revolve on its axis, it is its duty to stand perfectly still, while its axis and the ship revolve under it. If the wheel of the machinery is perfectly balanced, then there will be no disturbance of its regular action by the law of gravitation, and if, with the compass, there is no magnetic disturbance, the card will stand quiescent, while the ship is supposed to revolve round and round under it. Of course in this experiment there will be a slight drag of the card, but this will be the same on all points alike, and will not, after the ship's head has passed the first point, interfere with its quiescence. If the machinery again is imperfectly balanced then the action of the flywheel will be very irregular, and there will be, in compass language, gravitating disturbance of its action, sometimes making it questionable whether the machinery will turn over its center. This irregularity is usually compensated by attaching in its proper place a balance weight to the wheel. But let us suppose this machinery left to work without this balance weight. The irregularities then occurring in each revolution will serve to illustrate the irregularities of the action of an uncompensated compass. As the ship revolves round and round, the card instead of being quiescent will have motion, at one point of the ship's revolutions its north will be drawn two points or more, according to the amount of disturbance, to the east of the magnetic north, and at another it will be drawn a corresponding amount to the westward and there will be, as in the revolutions of the flywheel, no uniformity in its

action. At one point of the ship's revolutions the changes will be slow and at another fast, and when, like the flywheel it is turning over its center it will appear to stop, and when at another point it will get over a number of degrees with a jump. All this takes place with an upright ship, but when she heels over all the irregularities of its action are much increased. The Liverpool Compass Committee many years ago stated that the heeling in some ships would have an effect on the compass to one and a-half degrees for every degree of heel, and yet few if any ships have ever had this dangerous source of disaster compensated. This, however, can excite no astonishment when it is remembered that all attempts to compensate the other sources of error, with even an upright ship, have hitherto failed. How therefore can an accurate course be expected from such a defective instrument? Nevertheless, "dead reckoning" when running for land in thick weather has nothing better to make a course and to turn unseen points.

The next thing to be considered is the force of wind and heave of the sea acting on the ship at right angles to her course. Here again science in her absence leaves behind no instrument with the navigator with which he can register the amount of broadside pressure and heave of the sea, or the amount of deviation from a straight course that these will give rise to. In this case also the navigator is left exclusively to that guessing old pilot "dead reckoning" again.

"Dead reckoning" notices broadside pressure, and makes an allowance for its influence under the name of "lee way." It does not, however, cost him any hard thinking to arrive at the amount to be allowed. With him, there is no great difficulty in obtaining it; one, two, three, or more points, according to his glance at the weather, is arrived at with a bound and a jump. There is nothing to check his guessing, nothing short of actual disaster, and should this occur, the blame and consequences fall exclusively on the navigator; they in no way affect him, and so he goes on guessing and guessing the thousands upon thousands of deviations from straight courses, which are continually occurring, the fallacy of which only those ships that meet with disaster ever bring to the light, and this he will continue to do until science finds out some more worthy pilot to leave with the navigator in her repeated long intervals of absence from him, or otherwise finds out some practical and more satisfactory means than has hitherto existed for the navigator to check all his assumptions and guessings.

Then there may be a drain of current acting at right angles with the ship's course, for who, at any time, can say that the surface waters on any part of the globe, at the time he is navigating them, are without movement and at perfect rest. "Dead reckoning" takes it for granted that where no current is noticed and marked on the chart as existing that there never has been any, and that there never will be, as he also takes it for granted that where a current is marked it is always running, and will ever continue to do so, and at the rate indicated. But even in well-known currents, such as the Gulf stream, on account of their variableness and the continual change of the ship's position, "dead reckoning" in his allowance for them is likely to be as often wrong as right. Such a current as the Gulf stream in its axis may run with some degree of uniformity, allowing for seasons and weather, but it certainly does not anywhere else within its marked limits.

Again, known currents with a velocity of one, or a half, knot, are marked on our charts, but are there no currents running from twelve to one mile per day? Certainly there are, for it may be questioned whether the surface waters are anywhere quiescent for any time together. Ought it, therefore, to surprise anyone, even where no current is marked, for a ship to be carried in a day's run six or more miles from her track, may be at right angles with her course by this one subtle agent alone.

Then there is the common log to measure the distance run. What a rough instrument it is on which to stake the interests of life and property when running for land in continued thick weather! When its character is considered, the amount of intelligence at command to heave it, the influences surrounding it to produce changes in its revelations, and

the difference of speed maintained in the interval of the two hours in which it is generally thrown, three per cent. margin for error would be the minimum allowance that could be made for a day's run of, say, 300 miles. Here, therefore, in one day, as the error may be over or under, is an uncertainty of eighteen miles. And yet, after all, the common log is more reliable than the patent. The ordinary lead descending in the water gives results in conformity with its theory, but the patent log towed on the surface water is very uncertain in its results and baffles all calculations, as no rate can be fixed to it; at one time it is over, at another time under, and all attempts to fix a percentage of rate, either one way or the other, utterly fail. In a steamer its results are very variable, and its changes are as frequent as those of the weather on which it appears to me in a great measure to depend. "Dead reckoning," however, has nothing better than these logs to measure the distance run, and when having to turn unseen points of land, some accuracy is necessary, in order to avoid danger on the one side and bewildering dead reckoning on the other, consequent on running in thick weather out of his intended track. When all the difficulties connected with accurate navigation in thick weather are considered, and the many disasters which that deceiving old pilot, "dead reckoning," has led to, coupled with the severity with which the navigator has been visited for only a misplaced confidence in him, it would only be fair that "dead reckoning" should be visited with some of the blame and have his certificate suspended also.

When all these things are considered, may not the navigator very appropriately say to science, who never seems at rest, but constantly at work finding out new and simpler methods to aid him in her presence to verify his position, "Enough, enough; where thou art present our path is illuminated with thy light; we have no difficulty then to contend with. It is only in thy absence that our difficulties commence, and these increase in proportion to the length of it. Canst thou not, considering all the interests that are at stake, leave with us some small ray or glimmer of thy light in thy sometimes long absence from us. It is well-known to thee that 'dead reckoning,' who is thy first offspring, has grown old and untrustworthy for these 'go-ahead' times. It is well known to thee that he has not made one single step of advancement to meet the requirements of this progressive age, and it is also well known to thee that on account of his great age he inspires in the inexperienced navigator a certain veneration and false confidence which too often leads to disaster and death. It is thy province to grapple with difficulties. In this almost untouched field there is ample room for the full exercise of all thy great powers. Leave with us, therefore, in thy absence something more consistent with the demand of these times of rapid transit, than that blundering old pilot, 'dead reckoning.'

Every navigator who aims at and loves accuracy, whether in narrow seas or in the broad ocean, will hail with satisfaction every new invention which in any way contributes towards its attainment, or any that will check the assumptions and guessings of "dead reckoning." Two instruments have recently been brought out, the one contributing largely towards making an accurate course, and the other to check the deductions of dead reckoning. I allude to Sir William Thomson's patent compass and patent lead. The former of these instruments if it does not enable the navigator to run his ship as though she were running on rails, at least it enables him to run nearer thereto than anything that has yet been supplied. From the time that the Astronomer Royal, in 1854, laid down the true theory for producing perfect compensation of an iron ship's compass until Sir William Thomson's compass was invented, it has not been attained. During this long interval I have utilized every opportunity, and tried every imaginable experiment with the ordinary compass to attain it, but owing to the weight of the card could not succeed in correcting the quadrantal deviation. The chain-boxes, fitted with chains that were generally attached to the binnacle for this purpose, had no effect, and the piles of chain that I used to apply in my experiments gave no appreciable effect either. I conclude, therefore, that with the old compass card, owing to its weight, to correct its quadrantal deviation is impracticable.

Sir William Thomson gets over this difficulty by inventing a card, so light in its construction that two iron hollow globes about eight inches in diameter, properly placed, make the correcting of the quadrantal error possible. With this card it can be even over-corrected, consequently it is a simple matter requiring no more scientific knowledge than is necessary to rate a chronometer, or adjust a sextant, to produce a really compensated compass. The advantage of all this towards making an accurate course must be apparent. Like a perfectly balanced fly-wheel of some machinery, it becomes uniform in all its action. While the uncompensated or partly compensated compass, whether liquid or otherwise, when the ship is running before the big seas of the Atlantic, is all wandering, Sir William Thomson's compass is quite steady. It is therefore quite an acquisition and most helpful towards making an accurate course, and more especially if the helmsman has it to steer by.

The neglect to heave the lead has led to much disaster, and many certificates have been suspended for it. It is generally taken for granted that it is a very simple process, and that there is not the shadow of an excuse for not constantly heaving it when near land. In fact many navigators have been regarded as idiotic for not keeping it constantly going, but it appears to me this state of idiocy can be reached on the other side. Going out as a hired transport on the Abyssinian expedition I was made, by the transport officer, to heave the lead going out of the Birkenhead dock gates. In the Royal Navy the lead has to be cast whether of use or of no use. It is a rule of the service, and must be carried out. There is in all this no extravagant demand, for the number of men there under command makes it an easy duty, and they can afford to expend labor where there is only a very remote chance of its being of any use. This is not so in the merchant service. The amount of labor at command there does not admit of its being expended on work that is not apparent will be of some service. As a result of their training, Royal Naval men too often judge harshly the shortcomings of the merchant service; they forget that no amount of tyranny that can be resorted to can obtain from a limited crew the same attention to details in navigation which can be obtained in the Royal Navy with double and treble the amount of men. Until, therefore, merchant ships are manned equally with the Royal Navy, it will be unjust to judge their management from the same platform, and it will be in vain to expect from them the same attention to details. With the limited crew of a merchant sailing vessel, in disagreeable weather, the heaving of the lead has always entailed considerable extra work on the watch at a time when men could be least spared for the duty. In a screw steamer the ship must be dead stopped to obtain a reliable cast, and to insure that the propeller does not cut the line. These, with many other difficulties attending its use, account for its frequent neglect. With a more simple method of casting the lead this neglect would vanish.

Sir William Thomson's patent deep-sea lead can be kept, if required, constantly going; and in those ships that have an after wheel-house, and conveniently near the taffrail, the machine can be worked inside and made a permanent fixture. This arrangement saves the attendance of one man at night to hold a light, as the wheel-house light can be hung in front of the indicator. Here, therefore, free from all weather, in a comfortable, lighted-up room, without having to haul in a wet and sometimes freezing line, two men can, if necessary, cast the lead every five minutes, with more satisfactory results than could be obtained by the ordinary lead and line without the ship were dead stopped. It is not my province to enter into the details of this lead, and I think it will be more satisfactory to the reader if I limit myself to its results.

While the casting of the ordinary deep-sea lead on a cold and dirty night is a most troublesome and disagreeable duty, the casting of Sir William Thomson's lead by two men only is little more to them than an amusement. Like every other instrument it requires a little acquaintance to manage it perfectly. To obtain this I commenced my experiments in the Atlantic, where there was no chance of touching bottom. After attaching the tube that measures the depth of the lead, the ship going twelve knots,

100 fathoms of wire were allowed to run out; in four minutes the cast was completed, and the tube showed a perpendicular depth attained of seventy-five fathoms. This experiment was repeated a number of times with about the same results. The conclusion drawn from them was that it was not prudent to allow the lead to descend with such velocity, and in all future experiments the amount of restraint put upon the drum at the same speed of twelve knots gave fifty fathoms for 100 fathoms of wire run out. This, I considered, was the safest speed to work the instrument, and made any further use of the tube, except in experimental cases, quite unnecessary. Having worked out the amount of restraint necessary, on the revolutions of the drum, to give the perpendicular depth one-half of the wire run out, with the ship running twelve miles an hour, it was easy to write out a rule for any other rate of speed of the ship sufficiently accurate for all ordinary purposes. With this rule I ran along the north coast of Yucatan, over the Campeche bank, for nearly two days, the lead going every half hour, keeping mainly, while along the coast in the soundings, between five and ten fathoms, without either the rule or the lead failing. Steaming, again, in the Mississippi, to and from New Orleans, the experiment was similarly repeated. Again, rounding the Florida reefs and coast, the same experiment was continued. Again, crossing the banks of Newfoundland, it was renewed; and, at last, from the Fastnet to the bar of the Mersey. I have therefore given this lead a thorough testing.

Here at least science has answered the aspirations of the navigator and supplied him with an instrument with which in her absence in thick weather he can check the deductions of dead reckoning, feel his way approaching any coast, sail along it without losing his track, round certainly and with confidence unseen points of land, and all without inconvenience to any one. With such a lead on board the neglect to heave it would indeed indicate some degree of foolishness, but the neglect to use the lead ordinarily in use proves only too much consideration for the crew's opinion on such matters, and a consequent dislike to tease and annoy them by forcing them to perform repeatedly what on a hard cold night is to them an exceedingly unpleasant duty.

GEOGRAPHICAL SURVEYING.

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I.

In this paper I shall present a scheme for the organization, the gradual development, and the prosecution of a geographical survey in connection with the Geological Commission,* which, in the efficiency of its results, will satisfy not only the present demands but also the future needs of the Empire of Brazil for very many years to come. In the rapidity of its progress, this survey will be especially adapted to a country of so vast an area and comparatively sparse population, and as an adjunct to the above Commission, and in great part carried on by the members of the same, without interfering with the ends of that body, it can be maintained at an expense so moderate as to be in conformity with the present desire for economy and retrenchment in the public service.

THE PROPOSED PLAN OF SURVEY.

The immense empire of Brazil is yet without reliable geographical maps. These are necessary to the national welfare. The question arises as to what

* Charles Frederic Hartt, Professor of Geology in the Cornell University, and Chief of the Geological Commission of Brazil, died on the eighteenth of March last, in Rio de Janeiro, where he was engaged in preparing the reports of his Survey.
His death, and the dissolution of the Commission, of which he was the founder and director, have prevented the realization in Brazil of the plan of Surveying proposed in the accompanying pages.

kind of maps will be sufficient to satisfy the imperative needs of the country and of science. The plan of survey which I shall advocate is a mean between that system which takes cognizance of every house in a village and every little undulation in the landscape, and that want of system in which are represented whole mountain-chains that do not exist, or actual topographical features are delineated with gross inattention to accuracy. It is a judicious mean between the slow and laborious processes used, for instance, in the Ordnance Survey of Great Britain, and the sketchy and unreliable information gained by the early explorers of the New World, from whose results our first maps were compiled. These last are scarcely more graphic and complete than our present maps of the moon, and in fact, speaking broadly, they are not so accurate as the latter, which are, in great part, photographs of the surface which they represent. With these mere hints of the geography of its country a people should not feel obliged to rest satisfied until it can sustain a minutely topographical survey.

AN EVOLUTION IN CARTOGRAPHY.

The demand for maps depends upon the population and civilization of a country. In the beginning a rough sketch will answer the purposes of the pioneer. As the region becomes inhabited better maps are wanted, and finally the people require the nearest possible approach to absolute accuracy in the delineation of topographical features. Map-making in every country must follow a regular evolution from the incomplete to the complete.

Reviewing the origin and growth of the cartography of a country, we see how faulty it is liable to be. The first explorer is the first contributor to the geography of a region. By way of illustration, let us follow one of these pioneers as he traverses Brazil from South to North. Following up a branch of the River Plate, he records the approximate directions and distances of his journey, which he obtains, perhaps by the use of unreliable pocket instruments, perhaps by an occasional glance at the sun and his watch, or, more probably, by estimating at night the latitude and departure which he has made during the day. At a certain period of his march he finds a river entering from an easterly direction, whose volume he measures with a glance of the eye. Farther on, he encounters a tribe of Indians, whose village is situated upon the west bank of the river; he counts their houses, and makes the number of these a key to the extent of the population. At the following night he camps at the foot of a cataract. Impressed by its grandeur, and also by a kind of optimism, common to early explorers, and which will not allow him to underrate any of the glories which he sees, he estimates its height to be at least twenty meters, when in reality it is but ten.

At a certain point whose latitude and longitude he determines in a rude and hasty way with the sextant which he carries, he leaves the main stream and follows a tributary to its head in the highlands, where he crosses the divide between the great Paraná—Paraguay basin and that of the Amazon. Upon the summit of the plateau he tests his altitude above the sea by noticing the temperature of boiling water, or by reading the indication of his single aneroid, unreliable methods which have been known to give results even a thousand meters wide of the truth.* Continuing down the Araguay, he observes the trend of the mountain-range along his route, and descending the Tocantins, he makes a similar survey extending to Pará.

We do not disparage the work of this man. Under the circumstances of hardship and peril by which he is surrounded he does all that is possible, and his report is really of great value until some more reliable exploration can be made; still, for all of that, it is none the less incorrect and incomplete.

It is from such sources as this that the material for our first maps is drawn. In

* Gibbon's observations at the head of the Amazon, both the mercurial and thermo-barometer being used, show a discrepancy between the two which is equivalent to 300 meters of altitude. The height of Mount Hood, in Oregon, as given by one authority, who determined it by the boiling point of water, is almost 2,000 meters greater than that indicated by the cistern barometer and by triangulation. In the writer's own experience he has encountered an aneroid record, upon one of the peaks of the Sierra Nevada Mountains of the United States, which made the height of this mountain to be 3,000 feet above its true altitude. It is a noteworthy fact that these preliminary determinations, made with the above faulty methods, resemble the estimates of the early explorers, inasmuch as they almost invariably give exaggerated altitudes; perhaps the opinions and imagination of the observer are allowed to form, in some unaccountable way, a factor in these results.

later revisions there may be introduced the results of desultory explorations of mines, railway routes and navigable waters, as well as the meagre topographical data acquired by the land surveyor in running boundary lines of private estates, but still, taken at its best, a map constructed in this way falls far short of its purpose as a picture of the confirmation of the earth's surface, or as a guide to the traveler, the geologist, or to the capitalist who wishes to invest his money in the development and internal improvement of his country.

FAULTS IN EXISTING MAPS.

In his compilation of the scattered information at his disposal the cartographer finds that a certain district of country has never been entered by the engineer. He knows, however, that two rivers rise somewhere in this terra incognita, and he feels it safe to predicate a divide between them. He also, thinks it safe to presume that this divide is a range of mountains, of greater or less height, and, in his desire to give an appearance of finish to his chart, he does not scruple to insert at this place an ideal mountain system, and represent it as drained by the upper tributaries of the two rivers, concerning whose headwaters in reality nothing is known. These physical features soon come to be reproduced, with more or less variation, in other maps, and in this manner errors are grounded in the national geography, from which they can only be eliminated by a systematic geographical survey. Like national myths they stubbornly refuse to give way until eradicated by true scientific research.

Supposing, on the other hand, that the compiler, accepting the report of the explorer, who claims to have discovered a range of mountains between the Rio Paraná and the Rio Araguaya, wishes to represent them upon the map. He has no mathematical data to insure their position, and no sketches or other information from which to draw their intricate topographical features, and so he evolves from his imagination an utterly impossible chain of mountains, out of place, artificial, conventional, and even mechanical in their regularity. These he depicts in that stereotyped form of delineation, which is known in the modern geographical draughting-room as the "caterpillar" formation.

THE RELATIONS OF GEOGRAPHY TO GEOLOGY.

Upon such an unfaithful map as this it is impossible to faithfully represent the geology of a country. If the geologist attempts to lay down his conclusions upon a sheet of this kind, its errors will continually clash with his truths. The configuration of the land, as it appears upon this erroneous drawing, might indicate that it belonged to a certain geological age, and that, in fact, it could not be referred to any other; the geologist, visiting and studying the country itself, finds that it is of a later and entirely different period. But if he paints it as it really is he publishes a glaring anachronism to the world, for the color which represents the rock of one geological epoch overlies, upon the map, the physical features which are peculiar to another age. As in the artistic and true delineation of the human figure every feature must be the exponent of anatomical structure, so in topography, every representation of topography must be true to geological structure. Ranges of mountains, mean disturbance or great erosion of certain strata, and each has its own characteristic features as sharply defined as those of an animal. This should be thoroughly understood, and those immense lines of sierras which are supposed to separate certain river basins, or are delineated in the very heart of regions of which we have no knowledge whatever, should be erased from the national maps until these districts can be explored. In the course of his travels the geologist may find some physical feature of great importance, which he wishes to portray, in area and position, upon his chart, but the best maps at his disposal represent a topography utterly at variance with geological structure, perhaps a sharp ridge of mountains where there should be a plain, and so they are of no use to him. Or he may find himself obliged to color the top of a mountain peak with the tint conventional to the bed of a lake, and in this manner science is made ridiculous.

To take an illustration nearer home, suppose that the group of mountains that

abut into the sea in the vicinity of Rio de Janeiro have intervening valleys filled with alluvium, which is really the truth. Suppose that the limits of these mountains have never been accurately determined, which is also true. In this case, it is easy to be seen that if the geologist lays down upon the map the alluvial deposits in their true extent, they will here and there encroach upon and overlap the rugged masses of gneiss, and in places will extend far up the steep precipices of the mountain side. To avoid this absurdity the geologist is forced to be as inaccurate as those who have gone before him, and, in general, every error in the geographical map must be continued and apparently sanctioned in the geological chart that is based thereon.

It becomes therefore absolutely necessary that the work of the geologist should be preceded by and based upon that of the geographer, and that he should work in conjunction with the latter. In the exploration of a new country the geological party should make its own topography; and in the United States of North America, where the experiment has been most efficiently tried, this is always the case.

A good geographical map would give, with sufficient completeness, all the leading topographical features of the region explored, delineating with especial care those peculiarities of structure which are the keys to the different formations. It would display the shape and position of bodies of water, and show how the direction of a stream is changed and determined by the accidents of a broken and displaced stratification, and by other circumstances of its boundaries. If restrained by cañon walls its route would be angular; down a steep gradient it would be direct; and in the level alluvium near the sea its track would be tortuous and broken into bayous. This map would distinguish between the rounded slopes of a synclinal valley and the abrupt sides and angular cross section of an anticlinal cleft; and between the sharp edges of the volcanic rock and the eroded angles of the sand-stone. If there was exposed a great "fault" in the stratification, it would show it at a glance, with its precipitous bluff of exposed strata on one side, and, on the other, its gentle declivity of tilted surface rock. And, drawn in contour lines, it would reveal, not only the heights of peaks and passes and other vertical distances from plane to plane, but also the various orographic forms, each of which is full of meaning to the geologist.

ECONOMICAL USES OF THE PROPOSED MAPS.

Aside from being quite indispensable to a scientific commission, in the various ways that have been mentioned, these maps can be made a graphic supplement to their report in numerous other particulars, and can be made to embody the stores of practical information which they gather incidentally to their regular work. Upon it they can display the valleys of arable land and the plains adapted to grazing. The forests of timber can be laid down, and, from this drawing, their areas and values can be closely estimated. Advantageous sites for colonies can be noted here. The superficial contents of coal-beds and ore-deposits are given, and not only does a geological chart reveal where the precious and useful minerals are, or may be found, but it also furnishes that negative information, equally valuable to the miner, which defines to him the larger districts in which it is impossible for them to exist, and in which, consequently, it is a waste of effort to search for them; it is here that the science of palæontology is especially useful. If any portion of the country lies at a great elevation, the altitude limits of the various forms of vegetable growth may be traced, and also the limits of the possible culture of grain, coffee, cotton, and the other principal products. In this manner the map is made a general statistical report upon the value of the national domain.

The economical ends served by a work of this nature in the development and settlement of a new country, cannot be too highly esteemed. Every stream of importance is surveyed, in all—except those minor branches whose courses can be traced in from the adjacent mountain stations—the frequent tests for altitude along its banks determining the rapidity of its descent. The amount of water-power which it represents, and its value as a motor for machinery, and as an agent in hydraulic mining and diamond-

washing. This profile of the bottom of the valley also decides the feasibility of railways or other lines of communication by this route, while the sketches of the adjacent hills show what room there is for such a road, and, in connection with this, the geologist's report will give a general idea of the rock or other material with which the engineer will have to contend and work. In the survey of a range of mountains careful readings for altitude are made, not only on the summits of the peaks, but also at the passes, or low depressions in the divide, while the slope of the descent from the summit to the valley will be delineated in contour lines drawn at such vertical distances as circumstances may require. It must be admitted that these contours will only approximate to their true places, yet their number will be correct, and their positions will be such that they will give with sufficient certainty the various gradients that occur in the ascent, so that, by counting the meters of rise for every kilometer of horizontal advance, as shown by the scale of the map, the engineer or capitalist, in his distant office, with this sheet before him, can form a very satisfactory idea of the practicability of a proposed railway, and can select the most advantageous route for the preliminary survey.

The meteorological data accumulated in the process of this work are valuable, not only in the determination of the vertical elements of the survey, but also as an illustration of the general laws of drought and excessive rainfall. At intervals throughout the country, the declination of the compass needle will be observed, and will be published for the guidance of land surveyors who may not be proficient in astronomical observation. The positions and supra-marine elevations of all villages, important fazendas, medicinal and thermal springs, ancient ruins or other discoveries in archæology, supplies of water in a dry country, or of pasture in a barren district, and all other places of interest to the traveler, will be determined. The roads and trails already in existence will be surveyed and mapped, while a leading object of this enterprise will be to find shorter and easier lines of travel. The explorer who opens a new pass through the mountains is a far greater benefactor to mankind than he who discovers and names a conspicuous peak.

Many of the national surveys of Europe were founded on military necessity, that is, the necessity of having correct information to govern the movements of armies in time of war and the incessant transfer of troops in time of peace. In some of these countries their early maps were withheld from the citizen, whose taxes had paid for their construction, and to as recent a date as 1857, in one or two cases, they were kept secret for use in some contingent war. This argument of military necessity will have but little weight in Brazil, whose rulers, knowing that a country strong in peace will also be strong in war, take the enlightened and advanced policy of encouraging the peaceful pursuits of life, as the surest basis of national strength. Still it must be acknowledged that these maps would be of excellent service in the administration of the affairs of distant provinces, in the transportation of military supplies, and in the garrisoning of frontier posts, although the country is to be congratulated that, for every soldier to whom they would be useful, a hundred immigrants would be benefited by them.

THE INTENTS OF THIS ESSAY.

While entertaining no wish to make this article popular, in the ordinary sense of the word, I shall seek to exclude from it all formulas, equations for computation, and other material, purely mathematical, upon which the surveyor bases his work, and as far as possible I shall avoid those technical terms which would be embarrassing to the reader who is not an engineer. The fundamental principles of geographical engineering are the same all the world over, and in every mathematical library there are books of reference which give all the laws and formulas necessary for a work of this kind. Therefore, nothing would be gained by their repetition here. Specialists in geodesy, astronomy, and hypsometry have investigated their various branches, have published their results, and these, in their purity, are applicable to any quarter of the globe. One, for instance, has applied the theory of least squares to geodetic computation; another has invented the zenith

telescope for latitude observations; and a third has traced the horary curve in the barometric record. All of these discoveries fall within the comprehensive department of the geographer, who supplements these studies by utilizing their results in his labors in the field and office; or, if he is about to write a brief exposition of the subject of geographical surveying, it is his business to describe, in a straightforward manner, the way in which practical application of these truths is made.

This paper will be, in general, a description of the most approved methods, the economical devices, and the practical results of a successful geographical survey, working in obedience to the directions of the chief of the commission to which it is attached, and covering such areas as may be designated by him as most worthy of geological and geographical delineation. From time to time, as occasion may offer, and especially at the conclusion, the project will be adapted to the Empire of Brazil, as it is quite impossible to propose a plan of survey which will be applicable to all countries. Although, as has been stated heretofore, the general principles underlying this kind of work are the same wherever physical laws prevail, and the face of the country is wrinkled with mountains and valleys and furrowed with the river-bed and cañon, yet there are physical conditions peculiar to every land, as well as circumstances of area, population, and wealth, which require that it should have its own type of geographical survey, and not copy too exactly those of any other nation.

THE BEST TYPE OF SURVEY FOR BRAZIL.

Considering the circumstances of area, population and wealth, it is evident that the national surveys of Brazil should be "geographical," in a very liberal sense of the word; that is, that they should be comprehensive in their scope, rapid in their execution, and sufficiently accurate without being too punctilious and too excessively minute. It is only within the present generation of engineers, and particularly in the western hemisphere, that there has grown up an important distinction between topographical and geographical surveying, and even now it is hard to define the limit between them. The latter is an outgrowth and extension of the former and an adaptation of it to the mapping of large domains at the least possible expenditure of money and time.

DISTINCTION BETWEEN THE GEOGRAPHER AND TOPOGRAPHER.

As one of the many points of difference between the geographer and the ordinary topographer, we may mention that the former, in his travels and surveys, accommodates himself to the roads, trails, or other open and easy routes that already exist, and it is but seldom that he finds himself obliged to make a path for his survey to follow. In the ascent of some mountains it may be necessary to cut a road, and in the measurement of the base line for his triangulation he may have to prepare the ground before him, but these are almost the only instances. The topographer, however, in tracing a contour line around the side of a mountain, or in making parallel profile sections of the land, is not allowed to deviate therefrom, and if the way is not clear, he must wait, perhaps at great loss of time, until his assistants have removed the brushwood, or whatever other obstacles may intervene; in this respect he resembles the railway engineer. Again, in the selection of the stations for his triangulation, the geographer makes the best possible use of the mountains of a country as he finds them, generally accepting them as they occur; though their arrangement, it may be confessed here, is not always in such well-conditioned triangles as he would desire. The topographer, on the contrary, delays his work by the establishment of arbitrary stations where natural points are lacking, and by the erection of artificial signals on those mountain tops which the former observes without such aid.

In the end it will be found that the topographer's notes are so numerous and in such detail that it may require several centimetres of map to represent one kilometre of the earth's surface; while to the geographer, who is satisfied with the general shape of a mountain-spur, the approximate width of a valley, and the more important bends of a stream, a scale of one centimetre to several kilometres may be sufficiently large for the portrayal of the earth as he finds it. But

it will also be observed, by an economical government, that while the typographer consumes several years in the survey of a thousand square kilometres, the geographer will obtain a very satisfactory knowledge of thousands of kilometres in one year. And, in general, the superior accuracy, or rather detail, of the former, is purchased at an expenditure of time and money so great that only the older and wealthier nations can afford the investment; while I hope to demonstrate that the geographer's results are sufficiently complete for the needs of Brazil.

THE GEOGRAPHER'S PROFESSION.

The geographer's work is a peculiar and difficult one, and one for which his ideas must become enlarged by a special training. This is a branch of our profession for which no training-school prepares its student and no text-book yet published can instruct him. This is a field in which the experienced topographical engineer, fresh from his labors on park and landscape, or on the detailed surveys of thickly populated Europe, finds himself unhandy and incompetent, for much of the experience and tradition that he brings with him is an incubus to retard him. To become efficient in this new service he must forget much of the rule and routine that he has learned, and accustom himself to taking broad and bird's-eye views of the country.

Strange as it may sound, he must make it a matter of duty and pride to overlook and neglect much that is near at hand, and remember that, although a mole-hill at a distance of a few feet subtends a greater visual angle than a mountain as many miles away, yet it is the mountain, and not the mole-hill, that deserves delineation upon his map. Hitherto he has been local and narrow in his range; he must now become geodetic, else he will accumulate a mass of minutiæ, whose representation would be infinitesimal on a map of the proposed scale, and which is hence but an incumbrance to his books, and even worse than cumbersome, inasmuch as its presence excludes other and more valuable data. In short, the topographer considers the earth minutely, and with a microcosmic view, but the geographer is a man of no such narrow horizon, and trains himself to look upon it as a macrocosm, or great world.

THE INSTRUMENTS USED.

Of scarcely secondary importance to the men of a geographical corps, are the instruments with which they shall work. The tools which have been devised for the ordinary surveys of land and landscape must be left at home with the slow and tedious method from which they cannot be divorced. In a work of geographical extent the spirit-level, chain, and tally-pins are out of place, and whosoever, making accuracy his plea, attempts to introduce them there, will find his own ends defeated by them. Once upon a time, for instance, an engineer was intrusted with the survey of a large tract of new country. A certain sum of money and a limited period of time were given to him, a stated area of territory was assigned to him, and in return the authorities expected of him the most accurate and impartially complete map that his means would allow.

The time and resources granted him would permit him to touch the country but lightly and by swift marches, but, as this was intended to be only a reconnoissance, nothing more was expected of him than to trace the conformation of the land in a general way. He was an honest and conscientious engineer, and so great was his zeal for accuracy, or nicety rather, that he was scrupulous to a fault. He abused the maxim which says that whatever is worth doing at all is worth doing well. For determining the altitude of stations along the route he used the spirit-level, and their intermediate distances were found by stadia measurements, which system, though considered incautiously rapid in topography, is too laggardly slow for the ordinary purposes of geography. In this manner he crossed his territory with a few lines of march whose profiles were as trustworthy as those of a railway survey, and far more accurate than the public interest demanded, while between them there were large areas untouched and unseen, and of these the public, whose agent he was, had commissioned him to obtain information. The failing of this engineer was a common one; he neglected to distribute his resources fairly and impartially, and while half of

his map is reliable the other half is conjectural.

It would be too long a task to describe in detail all the instruments used in geographical work, or to rehearse all of the devices employed in its prosecution; however, the most necessary and novel features will be noticed here. At the basis of the work is the transit, or theodolite, which, with compass-needle attached, is the engineer's constant companion, without which his occupation is gone, no matter in what field his labor may lie. As an appurtenance to this, not the chain nor the stadia, but the odometer wheel, has become the recognized means of linear mensuration in the survey of streams and the determination of those distances of route and detour which are so useful in filling in a triangulation chart. Instead of the level, the cistern barometer gives the heights of mountains, mines, passes, camps, villages, and other important positions, while the aneroid barometer, portable as a watch, and as easily read, will tell the altitude of minor points and give with sufficient closeness the data from which may be plotted the profile of the odometer's itinerancy.

THE PERSONNEL OF A GEOGRAPHICAL CORPS.

These are the three classes of instruments that are indispensable; the purely geographical party required to use them need consist of but three men, the engineer, the meteorologist, and the odometer recorder. To this corps it may be deemed advisable to add a fourth member to act as an assistant to the engineer, and, by personal obervation and experience acquire that facility in the practice of his profession which will fit him, in the course of a brief period of training, for the responsible position above him. Such a person should already have the theoretical education of an engineer, and some skill in drawing. If it is not practicable to make this addition to the corps, it is well to choose as an odometer recorder one who possesses the acquirements stated above, and to consider that position, whose appertaining duties are light, as preparatory to the grade of engineer. As for the meteorologist, his is an intricate science which connot be studied too thoroughly, and barometric hypsometry, should be regarded as a profession quite distinct from the engineer's, although necessarily subordinate to it.

The various duties involved in the measurement of the base-line, at the opening of the season, may demand the services of a larger body of men than this, but, once in the field, any addition to the above number, except as muleteers and servants, will be superfluous, as far as the geographical work is concerned. One surveyor can see as far as two, and one man is able to take note of all of the country visible from his route of travel. No axemen are needed, for if there is a tree in the way, the line must yield to the tree; the resultant error will be trifling and will not be apparent in a map which represents several kilometres of territory on one centimetre of space. Neither is there any necessity for rodmen, with rods of two targets for micrometer measurements or one target for levels, who would retard the corps by the long delays consequent upon their transfer from the stations in the rear to those in advance. This party travels as a unit, moving as fast as its animals can walk, and is never broken, a consideration which is of value in a country of hostile people.

Of course the scope of the work may require the service of a great number of professional men, but its best progress demands that they should be divided into corps of the above size, which shall work in concord and under one general head. This director will assign to each party its territory for the season, and upon the borders of these areas, the various engineers will make rendezvous from time to time, as circumstances may admit, with their neighbors of the adjoining fields, for the purpose of reorganization, exchange and issue of material, and especially for the comparison of sketches and geodetic data, so as to insure the proper union of their several schemes of triangulation. In order to make the different systems of triangles interlock in one grand plan, the observer will frequently be obliged to read angles to stations which lie on an adjacent district, and which will be occupied by his co-laborers for the purpose of reciprocal observations. It is therefore necessary that they should meet in

occasional conference for the mutual identification of those stations.

THE STATIONS OF SURVEY.

Guided by these thoughts, let us suppose that we have completed our organization for a season in the field, and that we are now on the ground ready for work, at the place selected as the initial point of the survey. As with all surveys, this one will be executed from stations, meaning thereby any points at which a tripod is planted and an instrument adjusted, angles are read and sketches may be made. Of these we shall occupy four orders, of which, in importance, and consequently in accuracy, the astronomical is first. Then comes the geodetic, or trangulation station; the topographical station, so designated for the sake of convenience; and, finally, the odometric, or route station. In addition to the ends which they are especially intended to serve, each of these will be a meteorological station as well. These five classes, with the incidental details pertinent to them, will now be considered in the order named.

THE ASTRONOMICAL STATION.

Since the positions determined by triangulation, or other system of survey in which terrestrial objects alone are considered, are only relative to each other and to the first station occupied, it is evident that a map may be completed, which, in itself, will have all of the exactness of perfect truth, but whose place on a projected surface of the globe will still be uncertain. A map of a continent may be made, and this may be of great use in the guidance of travelers across the continent, and for the local information of its inhabitants, but still it does not play its proper part in the grand plan of this earth's geography, and define the situation of this land relative to the other continents of the earth, until it is bound into place by the meridians and parallels, which are the warp and woof of the structure of geography. Therefore, in order to adjust our map, when made, into its true place, we must have the absolute determination of one or more of its positions.

Now there is but one way of finding the absolute position of an object on the earth, and that is by going beyond the earth, consulting the stars, and ascertaining its place relative to them. Having two triangulation stations thus located, the whole chart becomes adjusted to its place. Or, having the latitude and longitude of our initial point and the astronomical azimuth of a side of a triangle leading from this origin, the former serves to pin the plot to the projected map, and the latter is instrumental in orienting it into the area to which it belongs.

POSITION OF THE ASTRONOMICAL STATION.

For every base-line measured and developed there should be an astronomical station occupied, and as a matter of convenience and co-operation they should be in the same vicinity, although it is not necessary that the station should be directly over either end of the base. Indeed, owing to great exposure to the wind, or to inconvenience of approach, it may not be found practicable to locate the astronomical station at any of the points of the triangulation system, or, to secure proximity to the telegraph, whose office may be hidden in the heart of a town, or the bottom of a valley, it may be so secluded as to be quite invisible from those points.

If so, it may be easily connected with them by running a careful linear survey from the astronomical station to the nearest geodetic station. If, owing to the disadvantageous nature of the ground, or other obstacles in the way, it may be impossible to measure the distance directly between these two points, the engineer can connect them by a broken line, reading at the astronomical station the angle between the meridian mark, already fixed by the astronomer, and the direction of his first course, and afterwards referring the direction of each measured section of his traverse to that immediately preceding. From these results he calculates, in meters, the difference of latitude and departure between the two points, and then, transforming the meters into seconds of arc, he computes their difference of latitude and longitude.

NUMBER OF ASTRONOMICAL STATIONS.

For a commission of moderate size, including one, two, or three engineering corps, the triangular development of one base will cover as much territory as can be surveyed by them in a single cam-

paign, and therefore one astronomical position a season is all that this survey would require during the first year or two of its organization. A series of observations extending through a couple of weeks, in favorable weather, or through a month at the farthest, will determine the geographical co-ordinates of our point of departure. These can be made by the astronomer while the engineers are measuring the base-line and developing the same, the director is perfecting his arrangements, and the purveyors are preparing and distributing the supplies, instruments, and all of those numerous articles of equipment which are the furniture of a scientific field season. At the same time, the meteorologist, by a set of hourly barometric and psychrometric readings accumulates data whose digest will give the vertical co-ordinate of this place with the possible error of a very few feet, and this completes the determination of its position with reference to a system of co-ordinates whose origin is at the level of the sea at the point where the first meridian crosses the equator.

For so short an annual term of service it might not be advisable to keep an astronomer constantly in commission, nor, at present, might it be well to go to the expense of the costly and elaborate instruments requisite for the best astronomical observation, provided that the co-operation of the Imperial Observatory could be secured and an astronomer could be detailed from there for that purpose. In addition to the gratification to be derived from the warranted excellence of the results which would be furnished by the skilled assistants of that institution, this corporation would be a matter of economy to the Government, and also, what is especially to be desired between any two scientific bodies, a means of friendly relation and interchange of information which would certainly prove of mutual value.

ASTRONOMICAL METHODS.

For the determination of the latitude of our point of outfit the zenith telescope would be used; while the longitude would be found by the telegraphic exchange of time signals, a method which has lately been so successfully introduced by the Astronomical Commission. The present wide-spread extension of lines of electric telegraph within the borders of Brazil is especially favorable for a survey of this nature, whose longitudes would be based upon telegraphic communication with the national observatory. The lines along the coast afford a general connection with the northern and southern provinces of the Empire, while, by the numerous branches which accompany the railways into the interior, points which lie far to the inland could be referred to the meridian of Rio de Janeiro, which, in its turn, has communication by cable with the observatories of Europe.

Thus it will be seen that the engineer need not be confined to any unfavorable locality in the selection of the ground for his base line, nor need the chief of the commission be restricted in his choice of areas to be surveyed. From the railways either constructed or contemplated it would probably be possible to reach any of the settled portions of Brazil without seriously overtasking the accuracy of the triangulation, and, if it were required to carry the survey still farther, longitudes determined by the method of moon-culminations would be sufficiently exact for the less important regions beyond.

ORIGIN OF THE TRIANGULATION.

An inland survey, based upon trigonometrical methods, progresses most successfully from an initial source concentrically outwards. The most fortunate location for the initial line is in the center of some broad valley or intermontane plateau, whose level expanse offers fair ground for the measurement of the base, and whose open field is favorable for the gradual and symmetrical development of the same until it shall reach the lines of the remotest triangles, in which it becomes a metrical standard for finding their length. In an extensive survey, lasting for years and covering broad territory, a series of bases are indispensable. These act as checks upon each other, and the net-works of triangles emanating therefrom are dovetailed into each other, and, in their adjustment to fit, each to each, what little error they may have accumulated is reduced to a minimum.

For instance, on each side of a range

of mountains there is an open basin. In each of these an astronomical station is established and a base is measured. On the comb of the intervening sierra, one-hundred miles apart, stand two pre-eminent mountain peaks. The latitude and longitude of each of these, with the distance between them, is determined from the two origins independently. They check each other, verifying, in their agreement, the accuracy of both systems, or showing by their disagreement that there is an error somewhere, and the long line, drawn by the labor-saving appliances of trigonometry, through a hundred kilometres of aerial route, a thousand meters above the valleys and chasms which it spans, is now ready to be used as a new base in the primary triangulation.

It may be difficult to find a favorable locality for the source of a triangulation immediately upon the sea-shore, as there, unless there are islands in the adjacent ocean, one side of the field is quite open and affords no stations to be occupied. If it were not for this objection it would seem best to measure a succession of bases along the coast of Brazil, and thence develop them westward. A triangulation is always most accurate in the vicinity of its origin, and as it becomes more and more remote from its initial ground it becomes less reliable, owing not only to the continued multiplication of the original error of the base, but also to the accumulation of inaccuracy, and mistake* from other sources. Now, the population of Brazil is thickest along the sea, and thence, into the interior, at least in many provinces, it gradually thins out. The importance of the country and the necessity of having truthful maps correspond to the density of the population. Add to this the fact that the most interesting geology of Brazil is on the sea-board, and, furthermore, the important consideration that the coast of a country, for purposes of navigation, demands a more rigorous geographical determination than the interior, and it will be seen that the triangulation upon which this delineation depends should not originate too far away. In a general survey of Brazil, therefore, the first series of astronomical stations and bases should be established, if not upon the sea-shore itself, at least upon the first plateaus that are encountered between the mountains of the inland.

* There is an important difference in the meanings of the terms "mistake" and "inaccuracy." If a man, carelessly reading a vernier whose indication is 38′ 45″, calls it 39′ 45″, he is guilty of a mistake. If from parallax or some defect in vision or judgment, he calls it 38′ 40″, he is inaccurate. Mistakes are due to want of care; inaccuracy, to want of precision.

POSITON OF THE BASE-LINE.

In its direction and position the base-line should bear judicious relations with certain hills, knolls, corners of terraces, or other prominent elevations in the vicinity, which may be selected as sites for the stations to be occupied in its development. The plans for its expansion, matured before its position is selected, should include two prominent peaks in the horizon, remote from the origin and from each other, whose distance apart this measured length will be instrumental in determining. The ground upon which it is to be measured, should be as smooth and bare as possible. It should be free from brush, tall grass, or other vegetation, and also from hillocks and gulches, which are serious impediments to a work of delicate mensuration. Whether it is level or not, provided its slope be gradual and even, is of secondary importance, as corrections may be easily applied to cancel the effect of its gradients.

LENGTH OF THE BASE.

The length of the base may vary from two to ten kilometres. In the opinion of many engineers more than four kilometres of measured length is zeal gone astray, for the advantages of accuracy gained by such excess would be obtained more easily by devoting the extra time to a more elaborate trigonometrical development. No arbitrary rule can be applied here, however. All must depend upon the judgment of the engineer, who will consider his surroundings, and if they are favorable for a slow and progressive development, a short base will answer, but if he is obliged to carry his triangulation from the base stations to the distant mountains by an abrupt transition, a longer one will be required, to prevent too great acuteness in those remote angles.

INSTRUMENT OF MEASUREMENT.

Since rapidity, as well as accuracy, is an object, we use a steel tape, ten or fif-

teen metres in length, as a measuring unit. In the swivel at one end of this there is a thermometer which tells the heat to which the tape is subjected at any time; there is also a micrometer screw, by which it can be lengthened or shortened in compensation for any possible change of temperature; and there is a dynamometer attached to govern the tension applied, which should amount to three or four kilograms, being at every application the same as it was in the original test for length, to which the tape was subjected.

Thus, as this apparatus is applied, in the process of measurement, it is under a constant strain, which preserves it from the error from sagging, to which all flexible cords are liable, and its length is always corrected to meet the contraction and expansion which the metal is constantly undergoing as the temperature varies. Should this micrometer be but incompletely graduated, so, for instance, as to be adjustable only for every five or ten degrees of thermometric change, or should it even be wanting entirely, very good results can still be obtained with the steel tape by reading the thermometer at every application, and, in the final computations for length, making the necessary temperature corrections. Used carefully and with intelligence, this instrument is one of the most valuable adjuncts of the geographical survey, and, in the hands of conscientious and interested observers, it is capable of results that are very near the exact truth; the error ought not to exceed one centimeter for every kilometer of measured distance.

METHOD OF MEASUREMENT.

The mensuration may be made on wooden plugs, with smooth, flat upper surfaces. These are driven firmly into the ground along the alignment at intervals equal to the length of the tape, and should be allowed to project above the earth sufficiently to permit this cord to swing clear of all inequalities in the surface, or other obstacles between the two stations. Or, instead of these, little stools of plank may be used; these should have short, pointed iron legs, to be forced into the ground, so as to hold the wooden block firmly in position.

When all things are ready a distance of one or two kilometers can be measured in one day. But, on account of any possible inefficiency in the compensation for temperature, and also because even the best assistants are liable to a personal equation in sticking the marking pin, some invariably inserting it to the right of perpendicular, and others the reverse, it is well that it should be measured several times, and by different persons, and a mean of the results taken. Then it should be leveled, in order that each tape-length may be corrected for its gradient, which is done by a simple trigonometric process, and finally it is reduced to its corresponding concentric arc at the level of the sea, when it is ready for use in the system of triangulation.

THE ASTRONOMICAL BASE.

The method of base-measurement by astronomical observation is sometimes resorted to in geographical surveying, but this process will be noticed here only sufficiently to point out the serious objections that there are to its use. Having the latitudes of the two ends of the base and the azimuth of one from the other, it is a simple matter to compute their distance apart. This seems to afford an economy of labor over the former method that involves the determination of the latitude and longitude of the first station, the azimuth of the base-line, and its length by direct measurement; this one requires the determination of the latitude and longitude of the first station, the azimuth of the base-line, and the latitude of the second station. The latter is apparently the simpler and shorter task, and since both methods are based upon astronomical observation they would appear to be equally reliable. But they are not.

Experience has long since taught the scientific world that the probable error of any ordinary astronomical result is several meters at the very least, and that it is not safe to put absolute reliance in those reports which give a latitude down to a very small fraction of a second. Now, in that system of triangulation whose position is based upon the astronomical determination of one point only, an error of a few meters in the latitude of that point will not do material injury. It will simply displace the entire trian-

gulation scheme, as a whole, so much to the north or the south, while, since the length of the base, or measuring unit of the proportions of this scheme, was accurately found, there will be no error in these proportions. But, in the astronomical measurement of a base, suppose its two terminal points to be in their most favorable position, that is, on the same meridian. The latitude determination of the southern station places it several meters too far to the south of its true position; that of the other, perhaps, makes it an equal distance too far to the north. Hence it follows that there is an error in the length of the base equal to the sum of the two astronomical errors, and this, in the development, is multiplied almost indefinitely, being repeated in any side of triangle as often as the length of the base is contained in the length of that line. This is supposing the base to be an arc of meridian; the greater its divergence from the meridian, the more seriously, for obvious reasons, will an error in the astronomical determination affect the length of the base. An astronomical base-line, therefore, should only be used when there are difficulties which make a direct measurement impossible.

THE DEVELOPMENT OF THE BASE.

In the early stages of the development, occuring, perhaps, on the level surface of the plain, it will be found necessary to use artificial signals. Great tripods of frame-work, ten or fifteen meters high, are constructed, leaving ample space within for the observer and his instrument. In erecting these, care must be taken that none of the legs of the tripod interfere with the view towards any of the proposed triangulation stations. Each of the signals terminates at the summit with a flag-staff, to which voluminous folds of white muslin are nailed, while the body of the steeple is wrapped with the same material and decked with loose tatters and streamers, which, by their ceaseless flutter in the wind, offer occasionally a surface from which the light is reflected to the eye of the distant observer. The same purpose may sometimes be better served by the use of glittering sheets of tin, or by a cone of the same material. These methods all have one very great advantage over the more accurate heliotrope, that is, they are always in position, and ready for observations to be directed upon them at any time. The use of the reflecting mirror, however, unless there are a number of heliotropes in the field, involves the loss of much time, as the instrument is transferred from one to another of the neighboring stations.

The development stations should be erected in conspicuous places, on high ground or the salient angles of bluffs, that the observer may know where to direct his instrument in searching for them, as it is extremely difficult to pick out the faint glint of a few yards of muslin on the broad light surface of a remote plain. As the development continues and climbs from the foot-hills into the high and peaked mountains, these natural points are sharp and distinct enough, being projected against the sky beyond, and the labor of station-building ceases, except in cases that are very unfavorable.

True, this triangulation by natural points is not so precise as it is in some geodetic surveys, and especially in the surveys of coasts, where even the phase of the conical signal is considered too important an element of error to be neglected; nor is it wise that it should be so, for a fault of a few meters in the position of a mountain-top in the remote interior of Brazil, located by this plan, is at present of no practical consequence, and the nation cannot afford to purchase an accuracy imperceptibly greater than this by an expenditure that would many times exceed the cost of this method of survey. Considering a mountain as a land-mark by which travelers are assured of their place and are guided as they go, it will be seen that, to men who travel by land, a small fraction of a kilometer, in latitude and longitude, is a deviation which they cannot notice; to the voyager at sea, however, the exact site of the sunken rock which he shuns should be known to him, in order that he may certainly avoid it. This is why the coast survey, in most countries, precedes that of the inland in the degree of accuracy which characterizes it, as well as in the amount of expense which attends it.

TRIANGULATION BY NATURAL POINTS.

It must not be inferred, however, that

the use of natural points in triangulation necessarily involves a serious accumulation of error. In general, the engineer, looking from one station to the next, can readily cover, with the thickness of the spider-line of his instrument, the highest ground of the distant mountain, and that point is selected as a correlative station, because that is the spot which can be most easily identified, either from a distance, or upon the ground itself. If this place is uncertain, as where there are a number of pinnacles of equal altitude, or not sufficiently prominent, as in a plateau summit, some peculiar object, as a solitary tree, or an isolated boulder, should be chosen as a center upon which to sight. If the profile of the mountain has but little curvature, its culminating point is usually determined by a pile of rock, a clump of vegetation, or other body upon its crest, which, although it may not be distinctly visible from a distance, yet has the effect of increasing the apparent altitude at that precise locality. In the same way the usefulness of a monument of rock, which a party should always leave behind it upon a mountain, as a signal to look back upon, does not terminate at that distance at which it becomes apparently invisible. The eye will still be impressed with the superior elevation of the place where it stands.

If the round top of a mountain is perfectly bare, and offers none of these accidental aids to the observer, it is well for him, in reading his first angle to it, to keep the horizontal cross-wire tangent to the surface, while he makes a careful and deliberate search for its highest point. Having decided upon this, he brings the vertical wire upon it, and then follows down the thread with his eye until he finds it bisecting some well-defined body in the field before him, such as a corner of rock or the trunk of a tree, and, in his repetitions of the angle he fixes the vertical wire always upon this object, while keeping the horizontal thread tangent to the surface. In this manner he secures to each of the following readings the advantages of the prolonged study given to the first, and not only are his results more accurate, as a whole, but they also agree better among themselves, which is always a source of gratification to the engineer.

THE MOUNTAINS OF BRAZIL.

In those lands which are remote from the equator the summits of the high mountains, of an altitude of three thousand metres or more, are above all vegetation and in the belt of perpetual snow, and their occupation is a work of great privation and exposure. The mountains of Brazil are exempt from that disadvantage to triangulation, as the climate is never rigorously cold here, and the elevation of the highest land is less than three thousand metres. The only obstacles to be feared here are the opposite disadvantages of too much vegetation, either hiding the tops of the peaks, or embarrassing the ascent to them, and too little height, whose result is liable to be a system of round, well-preserved, and insufficiently pointed mountains. But if those in the vicinity of Rio de Janeiro are to be accepted as a criterion, nothing more could be desired in the way of natural aids to triangulation.

PROGRESS OF THE TRIANGULATION.

In some cases it may be absolutely necessary to send a party in advance to erect monuments of stone, or signals of timber upon proposed stations which are at the same time important and unfavorable for observations; or, should the mountain be covered with forest, it may be necessary to send axemen to clear away all but the largest and most central of these trees. Such action, however, causes a vexatious delay on the part of the engineer, and is contrary to the fundamental principles of this method of survey, whose work should be a steady and unretarded progress, and should be reconnoissance and completion in itself.

From the top of his first high mountain station the engineer sees his allotted territory spread out before him, and he immediately begins to lay his plans for the coming season. He selects two distant peaks, which, with his present station, will form a grand triangle. Beyond these, far in the distance, there is yet another, and these four constitute a great quadrilateral, the lengths of whose diagonals may each be determined by two independent sets of observations, checking each other. In like manner he makes the circuit of the horizon, util-

izing, as best he can, the peaks which rise around him.

Although, owing to the many obstacles and unforeseen difficulties which are experienced in traveling through an unknown country, he may be compelled to modify and alter his first plans very often, yet as soon as he abandons one feature of his scheme he immediately adopts a substitute to take its place. To be provided for such an emergency, if a distant peak, as, for instance, one of the sharp pinnacles of the Organ Mountains, should appear impossible of ascent, he will select another in the same vicinity, and consider that as an alternate to the first, reading angles to it and treating it in all respects as a regular station as long as such a reserve may seem necessary.

In proceeding from one mountain to the next he surveys all of the intermediate country, his course being governed by the advantages and obstacles which present themselves from day to day. His route should never be an arbitrary one, determined at a distance and weeks beforehand, but he should be free to act upon the spur of the moment, following a stream to its source here and surveying a lake there, according as these geographical features may be encountered. If these features are depicted on maps already made, then there is no need of a second survey of the country; if they are not, he is not likely to know of their existence until he finds them.

EQUIPMENT OF THE PARTY.

Since the terminus of a day's survey cannot always be advantageously decided upon, even in the morning on which it is begun, it is especially desirable that the party may carry with it its own equipage and supplies, so as to be prepared to camp anywhere that night may overtake it. As it is a part of the policy of geographical work that the engineer should never follow the same route twice, a survey carried on by daily excursions from fazendas, settlements, or other fixed points of supply, returning to this base by the same road in the afternoon, would cost a great waste of time and energy. The necessary outfit of a scientific corps, consisting of instruments, clothing, cooking utensils, and provisions, can be carried by a train of pack-mules equal in number to the people whom they accompany. With this equipment the party are independent, and can camp anywhere that wood for fuel, forage for the animals, and a supply of water are found. This arrangement is particularly necessary in the occupation of a mountain station, upon which, for successful observation, it may be imperative to arrive at an early hour in the morning and to remain through the greater portion of one, two, or three days. From a camp near the summit this may be reached in an hour or two; but from a distant base almost the entire day would be consumed in the journey to and fro.

THE TRIANGULATION STATION.

The mountain will be ascended by the engineer, the meteorologist, and such assistants as may be required to carry the implements of the work and the food and water necessary for the maintenance of the party, and to build the stone monument, which, if possible, should always crown the peak, to receive the records deposited here, to assist in the future identification of this station, and to serve as an object upon which to direct the telescope in subsequent observations. One day will be a sufficient time of occupation for the ordinary triangulation station, provided the weather be favorable. To the more important ones, however, it may be advisable to devote two days, spending one night upon the crest in astronomical observations for the determination of the azimuth of some line radiating from here; this will serve as a check upon its computed value, as derived from the original azimuth determination made by the astronomer at the base-line. In times of high wind, or cloudy and stormy weather, especially liable to occur upon the summits of peaks, it may be several days before satisfactory results are obtained, and therefore the party should always go well equipped for a prolonged stay in their mountain camp.

PROFILE SKETCHES.

As an economy of time, which is of the greatest value here, the observer should make all reasonable haste in his operations. Especially is this so in his sketches, over which he must not linger, which, if he is anything of an artist, he

will be sorely tempted to do. He may see before him broader views and scenery more grand and impressive than ever was painted yet, but picturesque effects are no business of his. To the geographer of artistic tastes there is great temptation to finish his sketch by inserting a pine-tree in the foreground, and, perhaps, an eagle's-nest in the tree; this is all very wrong, as such dalliance may cost the omission of that far distant peak, which is printed like a fine point against the horizon, and which, insignificant and low as it appears, is yet of vital importance to his scheme.

His sketch is perforce but the outline and skeleton of a picture. Two converging straight lines, with a few strokes of shading, hastily thrown in, are sufficient to represent the ordinary mountain peak. Yet, if the peak should possess any oddity or marked individuality of shape, this feature should be preserved and even magnified in the drawing, as a key to the identification of this point when seen from elsewhere at some other time. Since any mountain, from different points of view, presents phases that are quite dissimilar, it is one of the greatest difficulties of triangulation to make sure of the identity of a station previously occupied, or, where there are a number of observers in the field, to secure uniformity in the choice of the same.

CONTOUR DRAWINGS.

The expert geographer is proficient not only in rapid profile but also in contour drawing, and on every mountain station he executes a contour plot of that scope of country which he sees beneath his feet, and of whose conformation he is reasonably certain. But in the preparation of this local plot he should not be too comprehensive, and go beyond the bounds of certainty into the outer limits of conjecture. Every mountain is surrounded by valleys, on whose farther side are other ranges perhaps as high as this, and they form the limit beyond which no contour sketch should presume to go, else it becomes conjectural and unreliable. It may include those environs of valleys, with a periphery of the foot-hills which are beyond them, and an indication of the cañons which indent the same, but no more.

In the office a contour sketch is accepted as truthful evidence of the ground as it really is, while a profile drawing is considered only a copy of the country as it appears to be, when uncorrected for the illusions of perspective, and is studied and deciphered accordingly. Looking abroad from this station, the successions of distant ranges, which are in reality separated by broad interspaces of valley and plain, are projected into a dense and circular wall, apparently unbroken by pass or intermission, whose serrated outline is seemingly as continuous as the horizon. It is an error to which the human sight and judgment are subject, and so, in orographic delineation, the impressions of the eye are to be received with caution, and only the readings of the theodolite are to be accepted in full faith.

PHOTOGRAPHS.

As a supplement to the pencil of the engineer, the photographer's camera can often be used to good advantage, in securing, in their true proportions, the many details of geological structure which are necessarily omitted from a hasty sketch. In the best geographical delineation of a country, a series of photographs are almost indispensable, as, aside from affording much material for the filling in of a map, they reveal the nature of the surface which they represent, showing whether it is regular or broken, well-preserved or eroded, whether a cliff is impassable or easy of ascent, and whether a coast is smooth and sandy, or irregular and rocky. All of these conditions should be made to appear in every good map, whether in contour lines or hachures, and particularly so, when, as in this case, the map is intended as a basis for geological representations.

READING THE ANGLES.

The instrument of triangulation is a theodolite, whose accuracy and weight increase with the minuteness of the graduation, but, in this work, in which rapidity and ease of transportation are to be considered, there comes a limit beyond which it is imperative to sacrifice nicety to portability. This is reached when the limb is graduated so as to discriminate to ten seconds of arc, between which divisions the observer may estimate to every intermediate five seconds.

With this he reads and repeats the angles, singly and in combinations, that lie between the visible points of the triangulation scheme. It is advisable to make at least six determinations of each angle upon each of the two verniers of the instrument, amounting to twelve repetitions in all. The greater the number of readings from which the mean is derived, the less will be the probable error of observation affecting that mean.

The observer may complete the repetition of each angle by itself, or, what is more convenient, he may read them in conjunction, by making six complete circuits of the horizon. In either case the graduated limb of the theodolite will be turned 30° in azimuth at every return to the initial point. In this manner each angle is read upon twelve different and equi-distant divisions of the circle, and the faults arising from eccentricity or imperfect graduation are reduced to a minimum.

The most opportune moments of the day will be devoted to this important test, and all other duties will be neglected for this. Successful triangulation demands perfect quiet and a clear horizon. In a dense and hazy atmosphere, or in a region of low clouds, the observer may find his opportunity in the evening or early morning, when the sun is behind the hills, and the rim of the earth is seen in silhouette against the rosy background of the sky.

SUBORDINATE ANGLES.

Upon the triangulation station the engineer also reads angles for the direction of the spurs which project from here and of the streams that debouch from here, estimating the distances of geographical features in his immediate vicinity. How far he may trust to his judgment in this respect, will be determined by the circumstances by which he is surrounded. It is the engineer's duty to make the best map of a country that is possible with the advantages at his command, and if he should see before him a tract of country, distant even ten or twenty kilometres, which he will never see again, he should take note of it on his contour plot; but if he knows that some future route of his will cross it, he can afford to neglect it now.

In addition he takes readings to inferior elevations which, although they may never be occupied for reciprocal observations, may yet be located by intersections from two or more triangulation stations. Some point, or "tit," standing on the edge of an abrupt bluff, where the rapid descent begins, is used as a means of marking the end of a neighboring mountain range. A solitary butte on the plain, insignificant in itself, is very useful in determining the locus of the stream which flows by the side of it. A promontory, jutting into the confluence of two rivers, is instrumental in fixing the place of their union. Sights are also taken to the junctions of streams, the mouths of cañons, and to the church or other central object of a distant village. A spot of green on the desert, evidence of a spring of water there, is located, for it will perhaps be camping-ground some day for himself or his co-laborers. A minute patch of white lake-bed, or red escarpment, or a solitary tree, is sighted upon, because on such a day he made an odometric station there, and this sight will serve to check his position.

NOMENCLATURE.

In his note-book and mind he has dubbed all of these things with graphic titles, or designated them by letters of the alphabet, and by these tokens he will know them when he sees them again. But this system of names is only a transient device for the assistance of himself and those who work in concord with him, and should not appear upon the printed sheet to the exclusion of the native and established nomenclature of the country, which should be investigated as far as possible, and, upon the final maps, should be adopted in preference to the arbitrary naming of any one man. The usefulness of a map, as a guide to the traveler, is in a great degree invalidated by a nomenclature which is at variance with that in use upon the ground itself. Perhaps the modern geographer is guilty of no more common and high-handed outrage against right, convenience, and beauty, than by ignoring the appropriate titles which abound in every country, however wild and uncivilized, and attaching his own, or by mutual and tacit agreement, the names of his comrades, to the mountains of that land,

thus announcing themselves to the world as nostrums are advertised on the pyramids.

THE TOPOGRAPHICAL STATION.

All of the preceding description that does not refer to the triangulation process is also pertinent to the topographical station. This term is applied to those isolated stations of survey, apart from the route of the odometer, and intermediate to the points of primary triangulation. They are more numerous than the primary stations, being usually scattered over the country at intervals of not more than twenty kilometers, but are less important, since there is no great responsibility of accuracy resting upon them. The topographical stations correspond, in position and numbers, with the secondary triangulation stations of a more elaborate geodetic survey.

A SECONDARY TRIANGULATION.

Even here the topographical station may be made a point in a subordinate scheme of triangulation if its situation is elevated, distinct, and capable of recognition from a distance. Of course, it is desirable that every occupied station should subsequently be made an object of reciprocal observations, and the engineer should neglect no opportunity to confirm his position in this manner. Each point thus fixed becomes the center of a plexus of triangles, of each of which the three angles have been observed; the total error of observation in these three angles becomes apparent, and the computer is enabled to distribute it judiciously among them before he proceeds to the computation of the sides.

For this reason the observer upon any topographical station will make careful search for other points which he may have occupied or may contemplate occupying, and will be more than usually cautious in reading angles to them. On his return to the office, at the end of the season, he will pick out from the multitude of his notes as many complete triangles as he may have observed, and these will be so much gain attained at a cost of but little extra labor. But if he makes it imperative upon himself to carry on a complete and systematic triangulation within the first, the additional refinement gained will by no means compensate him for the disadvantages of reconnoissance and delay which this involves.

It is safe to say that it is a longer and more laborious work to accomplish an unbroken secondary triangulation than a primary, as the stations are more numerous, less elevated and conspicuous, and oftener in the shadow. On the other hand, the results are by no means so valuable. The primary triangulation sustains the general and continued accuracy of the survey; the secondary does little more than to insure the individual positions of its own stations.

POSITION OF THE TOPOGRAPHICAL STATION.

Although not necessarily a point in the triangulation proper the site of the topographical station must afford angular data sufficient for the determination of its position by the three-point problem. After that, its predominant idea is that it is a means of local geography, or topography, and a center for a series of contour sketches. In addition to these detailed plots of the country in the immediate vicinity, profile drawings of the more distant regions are made. Then, by lines of sight, which shall be intersected by other rays from other topographical or triangulation stations, the most prominent features within a radius of twenty or thirty kilometers are crossed, and, as a precaution, angles are also read to all eminent points visible at a greater distance, even to the horizon, as they may come into use in some future dilemma in map-drawing.

While the sight of the topographical station should be as elevated and marked as possible, yet any hill, however humble and inconspicuous, or even the level surface of a plain, may serve this purpose, provided that there be three triangulation stations, or other known points, visible, and there is any useful information to be gained by lingering here. A few hours are usually enough for its occupation, and the route between points of triangulation should be marked at regular intervals by the monuments of these stations. It is a good plan for the engineer to make a practice of diverging from his route at some point in each day's odometric survey, and, ascending a suitable eminence close at hand, make a topographical station there. As far as

a general rule can be given for the occurrence of mountain stations, it is advisable for the party to advance by linear survey every second day, remaining in camp on each alternate day, while the engineer ascends some peak in the vicinity for the purpose of establishing a topographical or triangulation station there.

The large triangulation theodolite should be used in the more important topographical stations, or those which may possibly be treated as points in a secondary triangulation, but for the sake of convenience, the small route transit must be made to suffice for those which are made in the course of the daily march.

THE ODOMETRIC, OR MEANDER SURVEY.*

The meander survey is useful as an adjunct to the triangulation, filling up its skeleton with that detailed information which alone can give practical and popular value to a map. It determines the courses of valleys and streams, the routes of roads and trails, the peripheries of lakes and basins, and the distances between springs of water, villages, areas of pasture, fords of rivers, and other points of interest to the future traveler. Finally, it is a commendable occupation for the engineer while on his way from one mountain station to the next, and, since it occasions no delay in the general progress of the work, as the engineer can, as a rule, meander as much road as his pack-train can travel in one day, its results are net gain to the survey.

In the theoretical journey of this kind, the engineer would follow the edge of the dividing ridge from one station to the next, from which lofty promenade he could see the earth like an extended scroll beneath his feet, and make a survey that would be exhaustive and complete. But in the real, hard practice, he finds this path an impracticable one, for it is broken by precipices and blocked by abutments often a hundred metres or more in height. His easiest route of travel is by the side of flowing water, whose tendency it is to evade abrupt cliffs and soften steep gradients into an average and even slope. Besides, along the streams there are trails made by the wild animals which come here for drink and covert, and by the people of the country who come hither to hunt and fish. Therefore, if the detour be not too great, the most expedient route from mountain to mountain, is down one valley and up another, and the geographer who traverses a valley without taking some sort of a survey of it, is culpably negligent of his duty. On the other hand, if in a block of mountains the pre-eminent peaks be occupied, and the streams which emanate therefrom be meandered, nothing more is needed for a most excellent geographical map of that country.

THE MEANDER TRANSIT.

It is supposed that all transportation of outfit, and all travel, even in the meander survey, is accomplished on the backs of horses or mules. Riding in the saddle, the surveyor can devote but one hand to the grasp and protection of his instrument, the feet of whose tripod rest in a holster attached to the left stirrup. To facilitate his secure hold, the members of the tripod are thirds of a cylinder, which fold into the smallest possible compass, and are easily held in the grip of one hand.

The instrumental part of the meander transit is neat, solid, and compactly constructed. Its graduated limb is of small diameter, and its horizontal vernier reads *to minutes* only, which is all very well, since no smaller divisions can be plotted on the map. This graduation is used in the occupation of topograph-

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* *Note to the Portuguese Edition.*—This term which is now firmly grounded in the technical language of geographical surveying in the United States, is a misnomer, and therefore, in introducing a corresponding one into the Portuguese, it will be well to adopt some more appropriate expression. For the reason, "odometric survey" will be used to designate line surveys in which the odometer takes part, and "route survey" (*caminhamento*) as a general term, to include not only the above, but also those in which distances are determined by time, by the chain where that method is employed, or by paces, whether of man or horse, and whether recorded by the pedometer or by direct counting.

As the meander survey is understood, where this expression is used, it is simply any survey following a zigzag line, whose angles in general, are alternately salient and re-entrant, as the line accommodates itself to the route of travel. But this word "meander," having been derived from the river of the same name, in ancient Phrygia, which was celebrated for its winding, sinuous course, literally means, "abounding in curves." It will thus be seen that the more a survey approaches to a true meander, the farther it departs from the first principles of accurate linear surveying, which dictate that it shall consist of straight lines and angles only. Since it is always to be regretted when a survey is confined to a true meander line, as for instance, in tracing the course of a road along and up the side of a mountain range, so it is also a matter of regret that this word should have been introduced into the language of engineering, apparently sanctioning a faulty survey.

ical stations, at those meander stations where the view is extended enough to make it profitable to linger an hour or so in the accumulation of notes and sketches, and at all those which are three-point stations as well. But in the general survey, not the vernier-plate, but the compass needle, is used, on account of its greater convenience. The compass box is graduated, from zero at the north, around by the left to 360° at the north again, so that a reading of 90° corresponds to magnetic east, and 270° to west. The field records are kept in this manner, and in the office the declination of the needle is first applied to each bearing, after which it is reduced to its true direction, preparatory to the plotting.

MAXIMUM STRESSES IN FRAMED BRIDGES.

BY PROF. WM. CAIN, A.M., C.E.

Contributed to VAN NOSTRAND'S MAGAZINE.

I.

THE writer has made the endeavor in the following pages to investigate, for the live loads assumed, the maximum stresses that can ever occur in the chords, as well as in the web members of a bridge; also the most economical height of trusses. In so doing he has necessaily gone over some old ground; in the briefest manner, however, consistent with logical development; and has compared, approximately, some leading American types of bridges as regards weight. The unit strains were determined by the modification of Launhardt's formula, proposed by the writer in the November, 1877, number of this Magazine, which, it was thought, was peculiarly adapted to the comparison of trusses, besides illustrating the "new method" of designating "Structures of Iron and Steel," which may possess interest at this time.

1. A Framed Bridge is generally composed of two or more *trusses* or *frames*, as AdB, Fig. 1; which lie in vertical

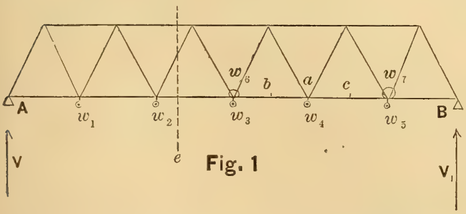


Fig. 1

planes, and are connected together by *bracing*, including the *floor beams*, on which longitudinal *stringers* rest, which support the cross ties and rails of a railroad bridge or the flooring of a highway bridge.

The upper and lower horizontal members of a truss are called respectively, the upper and lower *chords*, the bracing between them the *web*. The members of the web that act always as ties are called *main ties;* those acting always as struts, *main braces* or *posts;* and those members that act alternately as ties and struts are called *counters*—a term likewise applied to pieces that are not strained appreciably by the dead load or any uniform load on the structure, but are strained when the live load is distributed in a certain manner.

2. As the roadway is supported by the top or lower chord, the bridge is called a *deck* bridge or a *through* bridge. The intersection as *a*, Fig. 1, of a web member with a chord is called an *apex*. The distance from apex to apex on the same chord will be called a *panel length*, a panel being the part of the bridge so included.

The truss, Fig. 1, rests upon *abutments* at A and B and is unsupported at the distance or *space* AB.

The pressures exerted by the truss against the abutments are resisted by their *reactions* V, V_1, equal to them, on the principle that action and reaction are ever equal.

4. The following suppositions, only approximately realized in practice, will be made :

The reactions V, V_1, will be assumed to be vertical.

(Bow, in his "Economics of Construction," has given many illustrations of inclined reactions, due to friction at the abutments, resisting expansion or contraction of chords. Its influence is generally small when the end of the bridge rests upon rollers.)

It is assumed that the bridge members are jointed, or free to move, at the apices, and that the resultant resistance offered by each piece coincides in position and direction with the straight line connecting the joints or apices of that piece.

For the computation of the chords, main ties, braces and counters, the weight of bridge and load will be considered as concentrated at the apices of the chord that bears the roadway, the weight one-half panel either side of an apex *a*, on and over *ab* and *bc* being considered concentrated *at the* apex *a*.

Other suppositions will be noticed further on.

5. In Fig. 1, w_1, w_2 . . . ., are the panel weights on one truss due to the weight of the bridge or *dead load*, w_6, w_7, the panel weight due to live load at the corresponding apices.

Call the horizontal distances from w_1, w_2, ..., to B, l_1, l_2, . . ., respectively.

Now it is a law of Mechanics that *when any number of forces acting on a rigid body and in the same plane are in equilibrium, the algebraic sum of their moments about any point in the plane of the forces is zero.*

Take the point B as the *center of moments;* then since V acts upward and the weights w_1, w_2 . . . . downwards.

$$V\times\overline{AB}-(w_1l_1+w_2l_2+\ldots)+V_1\times 0=0,$$

or denoting $(w_1l_1+w_2l_2+\ldots)$ by Σwl, Σ denoting *sum* of similar quantities, we have,

$$V=\frac{\Sigma wl}{\overline{AB}} \quad . \quad . \quad . \quad . \quad (1)$$

The above law of course holds if we take moments about *a*, or any other point in the plane of the truss.

6. Again *it is a law of parallel forces in equilibrium that their algebraic sum is zero.*

$$\therefore V+V_1-\Sigma w=0 \quad . \quad . \quad (2)$$

Σw being put for $(w_1+w_2+\ldots)$.

When one reaction then is known the other can always be found.

The reactions V, V_1, with the weights of bridge and load w_1, w_2, . . . are called the *external forces.*

7. Now suppose the truss cut along the line $\overline{de}$; conceive forces C, R, T, applied at the cut parts *equal* and *directly opposed* to the *resistances* of those members, and let the part of the truss between B and $\overline{de}$ be removed. Then calling the sum of the weights w_1, w_2 . . . between A and $\overline{de}$, Σw; the forces C, R, T, V, Σw, must hold the part of the

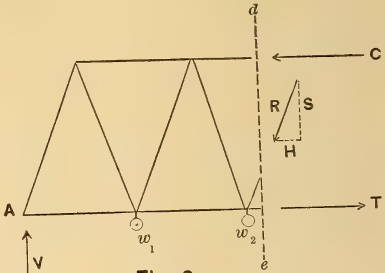


Fig. 2

truss between A and $\overline{de}$ in equilibrium, since C, R and T are equivalent to the action of the external forces to the right of the section $\overline{de}$.

8. Denote the vertical component of R by S, its horizontal component by H. Call the forces V, Σw, C, R, T, the *acting forces.* Then from Mechanics the algebraic sum of their vertical components equals zero

$$\therefore V-\Sigma w=S \quad . \quad . \quad . \quad (3)$$

Also the sum of the horizontal components of the acting forces equals zero,

$$\therefore C+H=T \quad . \quad . \quad . \quad (4)$$

S, the vertical component over any panel is called the *shearing force* for that panel and is always equal to the reaction V—, the sum of the downward forces from A to the section considered.

9. If i denote the inclination of the web member cut to the vertical then S sec. i is the total stress on the web member.

From eq. (1), we find V; from eq. (3) S, whence the stress on any web member cut follows.

10. Note that *ip*S=V$-\Sigma w$ is +, the *resistance* of web member cut acts in the same direction as V, *i.e.* upwards; R acts

downwards, and the *strain on the tie-brace cut is compressive if its top leans away from the abutment* A; *otherwise tensile;* since in the first case H acts to the left, in the last it acts to the right in order that R, the resultant of H and S may act in the direction of the web member cut as was assumed. Let the reader conceive $\overline{de}$ removed one panel to the left and illustrate the last case with a drawing. Also the two following.

11. *When* $V-\Sigma w$ is $-$, then S acts upwards, therefore, *a web member whose top leans towards* A *is compressed, otherwise it sustains a tensile strain.*

The last two cases occur, for a uniform load when the section $\overline{de}$ is taken to the right of the center.

These rules are especially useful in treating continuous girders or draw-bridges.

12. *Maximum Strain on Web Members.*—The strain is greatest when the corresponding S is greatest; and S *is a maximum when the live load, the heaviest part in front, extends from the farthest abutment to the panel considered* ($\overline{de}$ Fig. 1).

(*a.*) For if any live load rests on the portion A*de* (Fig. 1), V is increased by a *part* of it only, whereas Σw is augmented by the whole of it, hence $S=V-\Sigma w$ is less than before.

(*b.*) Again, if any load on part B*de* is taken off, V is diminished, but Σw is the same as before, hence S is less than before.

(*c.*) If the live load, distributed as before, is placed with its front at the apex to the left of $\overline{de}$ and extending to the *nearest* abutment A, then $V_1 < V$ and since Σw between B and $\overline{de}$ is greater than Σw to left of $\overline{de}$ therefore, $S=V-\Sigma w$ is less than before.

(*d.*) The heaviest part of the live load must be in front, for then V is greatest.

We conclude as was enunciated.

13. In case (*c*) if the stress caused in a web member is of an opposite kind to that caused by the maximum shearing force, the member must be designed to resist alternately both stresses, or a counter must be added to the panel considered.

14. *Live Load.*—On this subject, see VAN NOSTRAND'S MAGAZINE for October, 1875, p. 305; also for May, 1877, p. 476; also the "Illustrated Albums" of many bridge companies.

The locomotive assumed for railroad bridges, in what follows, concentrates 84,000 lbs. on six drivers, three on each side, on a twelve feet wheel base. The locomotive and tender covers fifty feet of track; the thirty-eight feet not covered by the drivers before and behind the engine is supposed loaded with 2,000 lbs. per foot ∴ total weight of locomotive and tender is $84000 + 38 \times 2{,}000 = 160{,}000$ lbs.

15. *Computation of Floor Beams and Stringers.*—The floor beams extend from an apex of one truss to the corresponding apex of the other truss. The stringers resting on them lie under the rails or parallel to them.

Then for six feet panel lengths and under, the center drivers can concentrate $\frac{84000}{3}=28000$ lbs. on floor beam or at center of stringers.

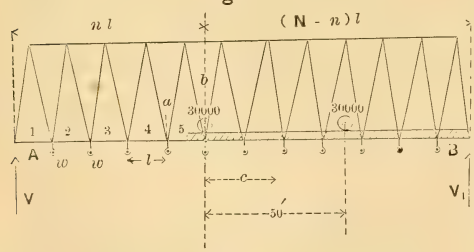
For twelve feet panels, let the center drivers rest on floor beam; the front and rear drivers being at center of adjacent panels, one-half their weight is supported by a *floor beam.* Its reaction from the 2000×6 lbs. in front and behind drivers$=$ $2\frac{2000\times 6}{4}=6000$; so that the floor beam sustains in all $28000+28000+6000=62000$ lbs. The stringers sustain 28000 at center, assuming that they are most strained when the *center drivers rest on their center.* For greater panels than twelve feet, assume approximately the 2000 lbs. per foot, extending from front and rear drivers to the nearest floor beam, and reduce the load to an equivalent center load P for the stringers load. Thus for a panel length of twenty feet: Moment at center due to P is $\frac{1}{2}P\frac{20}{2}=5$ P. The moment at center due to the actual load is, $50000 \times 10-28000 \times 6 - 8000 \times 8 = 268000$; which, equaled with the other moment, gives $P=53600$.

The maximum loads on floor beams are concentrated directly under the rails and are found by supposing center drivers to rest directly over floor beam. See arts. 43, 44 further on this subject. The following little table is made out on the above basis, and is intended to give average results :

Length of Panel.	Floor Beams.	Stringers equal to center load.
6 feet & under	28000	28000
9	48666	28000
12	62000	28000
15	72400	38467
$16\frac{2}{3}$	77492	44987
20	86800	53600

16. *Live Load for Web Members and Chords.*—The live load assumed for web members consists of two locomotives as above on 100 feet; there being not less than fifty feet between center driving wheels of locomotives; followed by cars weighing 2000 lbs. per foot for rest of span. For panel lengths over twelve feet, the disposition is as in Fig. 3, the 2000 lbs. per foot in front of drivers extending to middle of panel. For panel lengths less than twelve feet, the locomotive will be supposed to be without truck wheels in front and hence no weight is assumed before drivers. The locomotive excess over 2000 lbs. per foot is $8400-12\times2000=60000$ or 20000 lbs. on each pair of drivers; *hence we assume for web members the bridge loaded with* 2000 *lbs. per foot up to the middle of the panel considered, and a locomotive excess of* 60000 *lbs. at foremost apex, also* 60000 *lbs. fifty feet back of this;* or a greater *distance if the strains are thereby greater. For chord strains, we assume the bridge loaded with* 2000 *lbs. per foot over the entire span, and with the locomotive excess, consisting of two weights of* 60000 *lbs. each not less than fifty feet apart; the latter to be so placed as to give maximum stresses on each chord panel in turn*, as will be fully shown in the sequel.

Fig. 3



17. If truck wheels are assumed in front of drivers, the shearing force is less than for the disposition above. For short spans especially, it seems desirable to assume as above that the foremost engine has no truck wheels, *i.e.*, when the panel lengths are less than 12 feet, or practically even for greater panel lengths.

18. *Web Strains.*—In Fig. 3,

w=weight per panel of one truss with its share of roadway and cross bracing.

p=weight per panel of cars[$=(1000\,l)$ pounds] for one truss.

l=length of panel in feet.

E=locomotive excess (=60000 lbs.) for one truss.

c=distance from front apex to its center of gravity (25 ft.)

N=number of panels (12 in Fig.)

n=No. panel considered, numbered from A as in Fig.

i=inclination of a tie or brace to the vertical.

Now to find the maximum shearing stress over the nth panel (5th in Fig.) by art. 16, the car load, 1000 lbs. per foot must extend to the middle of the nth panel; we also have, 30000 lbs. at apex on right of nth panel and 30000 lbs. 50′ to the right of the last. Next (Art. 4), the car load $\frac{1}{2}$ panel either side of an apex is regarded as concentrated at that apex.

19. Now take the right abutment as the center of moments. The lever arm of V is Nl. There are (N−1) weights w, whose resultant acting at the center of the span, has a lever arm $=\frac{1}{2}Nl$. There are (N−n) weights p, whose center of gravity is $\frac{1}{2}(N-n+1)l$ from right abutment ($\frac{1}{2}$ Ba in the Fig.) and lastly the locomotive excess E has a lever arm, $Nl-(nl+c)$

Therefore art. 5,

$$VNl=(N-1)w\tfrac{1}{2}Nl+(N-n)p(N-n+1)\frac{l}{2}+E\,[Nl-(nl+c)]$$

Or calling the shearing force over the nth panel S_n, we have, art. 7,

$$S_n=V-(n-1)w=\left\{(N-2n+1)\frac{w}{2}+(N-n)\,(N-n+1)\,\frac{p}{2N}+\frac{E}{N}\left(N-\frac{c}{l}-n\right)\right\} \qquad (5)$$

When the rearmost engine is not on the bridge, E, in the preceding formula, becomes 30000 lbs. and $c=o$.

20. Having found maximum S over each panel, as *e.g.*, the 5th, the stress on the post = S sec. i, that on the tie is S sec. i_1; i and i_1 denoting the respective inclinations of the post and tie to the vertical; art. 9. There is the same shearing stress on tie and brace over the same panel, and this evidently (see the reasoning of art. 7) holds when the posts are vertical as in the Pratt Truss, or the ties vertical as in the Howe Truss, or when the ties and braces are equally inclined as in the Warren Girder, or unequally inclined as in the above figure. We shall use this equation in discussing the bowstring and other forms of girder likewise. An example will best illustrate the use of the equation and the theory of counters.

21. *Example.*—Let the span AB=200 feet, divided into N=12 panel lengths of 16′ 8″ each; weight of bridge 336000 lbs. or 168,000 lbs. to each truss $\therefore w=\frac{168000}{12}=14000$; live load as in art. 16 $\therefore p=1000\ l=\frac{50000}{3}$, since $l=\frac{50}{3}$; E=60000, c=25. Substituting these values in formula (5), we get:

$$S_n=(13-2n)\ 7000+(12-n)\ (13-n)\ 694+(10\tfrac{1}{2}-n)\ 5000.$$

	S	$\triangle_1$	$\triangle_2$
S_1 = 77000+11×12×694+47500=	216108	34268	—
S_2 = 63000+10×11×694+42500=	181840	32880	1388
S_3 = 49000+ 9×10×694+37500=	148960	31492	1388
S_4 = 35000+ 8× 9×694+32500=	117468	30104	1388
S_5 = 21000+ 7× 8×694+27500=	87364	28716	1388
S_6 = 7000+ 6× 7×694+22500=	58648	27328	1388
S_7 = − 7000+ 5× 6×694+17500=	31320	25940	1388
S_8 = −21000+ 4× 5×694+12500=	5380	24552	1888
S_9 = −35000+ 3× 4×694+ 7500=	−19172	—	—
S_{10} = −49000+ 2× 3×694+ 5000=	−39836	—	—
S_{11} = −63000+ 1× 2×694+ 2500=	−59112	—	—
S_{12} = −77000 =	−77000	—	—

The rearmost 30000 locomotive excess leaves the truss for S_9, whence the formula is then modified by putting $c=o$ and E=30000, to compute S_9, S_{10} and S_{11}.

22. The common differences for the terms $(13-2n)$ 7000 and $(10\frac{1}{2}-n)$ 5000 are 2×7000 and 5000 respectively; from which those terms are quickly computed. Column $\triangle_1$ is found by subtracting each value in column S from the preceding value. Column $\triangle_2$ is the common difference of the quantities in column $\triangle_1$. In fact if in the proceding equation we change n to $n+1$ and subtract the last equation from the first we get,

$$(S_n-S_{n+1})=-\frac{p}{N}n+\left(w+p+\frac{E}{N}\right),$$

the equation of a straight line which makes an angle with the axis of abscissas (n) whose tangent is $-\frac{p}{N}$.

Giving values to n : 1, 2, 3 . . . . , the common difference between successive values is, $\triangle_2=\frac{p}{N}$. On computing S_1 $\triangle_1$ and $\triangle_2$; by reversing the above method of deducing columns $\triangle_1$ and $\triangle_2$ we can find the various values of S.

23. The "shears" may be found graphically if desired by drawing the straight line given by the equation above, taking off in dividers the differences between successive shears $(S_n - S_{n+1})$ which are represented by the ordinates to the line and subtracting these first differences in order from the line taken to represent S_1, thus giving lines which measured to a scale will give S_2, S_3 . . . , provided always that both engines remain on the bridge.

Thus making n=1, we have

$$(S_1-S_2)=-\frac{p}{N}+w+p+\frac{E}{N},$$

for the *difference* between the shears in the first and second panels. Lay this difference off vertically above the lower apex one panel to the right of the left abutment, regarding the lower chord as the axis of abscissas (n). Also lay off the value (S_6-S_7), say, at the 6th apex from the left abutment; the line joining the extremities of these ordinates will cut off the successive differences $\triangle_1$ from

ordinates erected at apexes 2, 3, 4, ... These ordinates, can be laid off successively on the line equal to S_1 by scale; thus giving S_2, S_3 . . . . , as before mentioned.

24. Having thus found S_1, S_2, . . . , the strains in the web members over panels 1, 2, ... are S_1 sec. i, S_2 sec. i, ... When a web member over the nth panel becomes vertical, its mass strain is simply S_n. If we form a column, S sec. i, to the right of column S (art. 22), and deduce $\triangle_1$ and $\triangle_2$ *from it*, we detect any error that may occur in multiplying by sec. i.

By art. 10, *when* S_n is +, the web members whose tops lean away from A act as struts; those whose tops lean toward A as ties. In this case, S is + for the first 8 panels, or 2 panels past the center. Now if the live load is supposed to move on from A toward B, we prove similarly that the web members whose tops lean $\left\{\begin{matrix}\text{away from}\\ \text{towards}\end{matrix}\right\}$ B act as $\left\{\begin{matrix}\text{struts}\\ \text{ties}\end{matrix}\right\}$ ∴ Therefore each web member, in this case, in panels 5, 6, 7 and 8, suffers both compression and tension in turn and must be designed for the maxima of both strains, *i.e.*, counter braced. This max. S over the 5th panel is when the live load extends from the farthest abutment, and equals $S_5=87364$. But when the live load extends from the nearest abutment to the 5th panel *from that abutment* as from B to panel marked 8 in Fig. 3, $S=S_8=5380$; and, as just shown, the web members previously designed as $\left\{\begin{matrix}\text{struts}\\ \text{ties}\end{matrix}\right\}$ for $S=87364$, must now be designed as $\left\{\begin{matrix}\text{ties}\\ \text{struts}\end{matrix}\right\}$ for $S=5380$, also. Similarly the web members of panel 6 are designed as $\left\{\begin{matrix}\text{struts}\\ \text{ties}\end{matrix}\right\}$ for a stress of 58648 *sec. i*, and also as $\left\{\begin{matrix}\text{ties}\\ \text{struts}\end{matrix}\right\}$ for a maximum stress of 31320 *sec. i*. We then design the web members up to the middle of the truss for the max. stresses, and those panels past the center for which S is positive, which may be numbered now from the other abutment, if preferred, (after S is found by form 5 by its numeration), have their web members designed for the lesser stresses of an opposite character to the maximum stresses.

25. If preferred, in place of causing the same piece to act *both* as a strut and a tie, we may insert a counter in the panel to beat one of the strains, designing the main ties or braces of that panel so that they cannot take a reverse strain and the inserted member is thus compelled to take it.

Thus in Figs. 5 and 6 the dotted lines are *counters that bear but one kind of strain*, like the main ties and braces of the truss.

26. When the live load, engines in front, extends from the *farthest* abutment, S_n is a maximum for the nth panel by art. 12.

When the live load, engines in front, extends from the *nearest* abutment to the nth panel, S being +, the strains induced in the web members of the nth panel are a maximum of an opposite character to the first.

The proof is the same as in cases a, b and d of art. 12.

27. *When the load extends from the nearest abutment and* S_n (*of eq.* 5 *is* —, as in panels 9, 10, 11, 12 of bridge assumed, the strains are not reversed (see art. 10), but we find from eq. (5) the *minimum strains* that can ever come on the web of the panels considered.

Thus we see in the example, art. 21, that S_9, S_{10}, S_{11}, are less numerically than if there is no live load on bridge, for the term $(N-2n+1)\frac{w}{2}$ involving the dead load is — when $n>\frac{1}{2}N$, whereas the two terms involving the effects of the live load are always positive.

Then, reasoning as in art. 12, we see that the *positive terms* are less for any live load in front of panel considered, or for any live load taken off behind the panel, and that the locomotives must be in front, therefore S_n is least numerically when the load, engines in front, extends from the nearest abutment, S_n *being negative.*

28. Observe that for a dead load alone, $p=o$, $E=o$, that $S_n=\frac{1}{2}(N-2n+1)\,w$, which gives the same value numerically, but with a different sign, whether $n=\frac{1}{2}N+m+1$, or $n=\frac{1}{2}N-m$, or for panels equally distant from the center. Thus the web members equally distant from the center and similarly placed with respect to it, are equally strained by a uniform load.

29. It is seen by reference to the method of deducing eq. (5) that it gives the maximum shearing force at any panel for any girder, framed or not, of span AB, *numbered and loaded as* AB *is in Fig.* 3; hence it applies to the inclined members of the Pratt, Howe, or triangular trusses (Figs. 5, 6 and 7) whether the load (live and dead) is all supposed to rest on the lower or upper chords, or both, provided the panel members begin *at* the abutment as in Fig. 3.

It is well to note carefully the position of the front engine that gives maximum strains on the *vertical* members of the Pratt or Howe types. Thus, in Fig. 3, the *shear* is the same on the two inclined web pieces of a particular panel. Now conceive the STRUTS TO BECOME VERTICAL by moving their tops forward; the *max.* shear they ever sustain is the same as that of the tie reaching to their top from the front engine, for the *through bridge;* but for a *deck bridge* this is not so. The max. strain on a vertical post then obtains when the front engine is directly over the post; whilst the ties are most strained when the engine is directly over the post that connects with their lower ends (art. 12). For a Howe bridge, THE VERTICAL TIES are most strained when the engine is at their feet for *a through bridge*, or at the top of the brace that connects with their feet for *a deck bridge.* The live load must never extend so far that part of it must be subtracted from V in finding S (art. 12).

Similarly, the *minimum shear* a web piece ever bears (art. 27) is when the live load extends from the nearest abutment as far as may be without Σw being increased by any of the live load in the expression, $S=V-\Sigma w$ (art. 7).

30. The formula does not apply to the Warren girder, or to Fig. 3, when the load is on the upper chord (concentrated at the apices); since the weights are not then distributed as in Fig. 3.

The methods of arts. 5 and 7 can then be used.

31. Let us now ascertain the extent of the error made by assuming that the load $\frac{1}{2}$ panel length either side of an apex is supposed concentrated at that apex.

a. Thus in Fig. 3 we vertically consider the $\frac{1}{2}$ panel of live load next B as removed. Except for very short spans its influence is very slight. In this case V, and therefore S, would only be increased by it $\left(\frac{p}{2}\,\frac{l}{4}\right)\div 12\,l=174$ pounds.

b. We have also disregarded the dead load $\frac{1}{2}$ panel next A and B. Including it, V is increased by $\frac{1}{2}\,w$; but $S_n = V - \Sigma w$ is the same as before since Σw is likewise increased by $\frac{1}{2}\,w$.

c. If the weight of web members is not supposed concentrated at the apices, but distributed as it really is, then $S_n = V - \Sigma w$ diminishes in the same panel the further the section taken (Fig. 2) is from the abutment; and still more if any chord piece and load be supposed borne (as it really is) at the apices of that chord piece.

This case represents exactly the true solution. Thus in $S=V-\Sigma w$, the term Σw equals the weights of chords and loads borne at apices from A to section taken, + the weight of web to section. Such refinement is generally unnecessary for medium spans.

In the triangular truss, shown in Fig. 7, the loads are supposed borne at the apices of either chord alternately so that one source of error is eliminated for this truss. In the Pratt the posts bear one panel weight of upper chord + part of their own weight above section taken over that given by eq. (5), for a *through* bridge; whilst for a deck bridge eq. (5) gives an excess of one panel of lower chord and weight of post above section over the true strain. A figure will illustrate this; also the modification for the ties of the Howe Truss.

d. In Fig. 3, we have supposed also the live load on the *n*th, or 5th panel in the Fig., extending up to the middle of the panel, to be concentrated at the right apex. Actually *part* of it is conveyed by the stringers and floor beams to *a* directly. Call P the reaction at *a* due to this part. Now V will be larger than on the former supposition and will be augmented by a *part* of P whereas Σw is increased by the whole of P; therefore $S=V-\Sigma w$ is less than given by eq. (5). Eq. (5) is then on the side of safety.

32. The true value of S can be readily found, but it is not advisable in practice to enter into such refinements, for the supposition of hinged joints, &c. (art. 4)

is never exactly realized in practice; hence the actual strains in a structure probably always differ from the computed, especially the components acting on the fibers most strained; again the hurtful effects of vibration, oscillation and impact, modify in an unknown manner the strains due to a statical load, therefore it seems useless to insist upon strict accuracy in such statical calculations.

33. To test further the method of apex loads: Suppose a uniform load q per foot, to extend from the apex b, to the right of a, a distance x to the left from b. Call a' and b' the parts of this load borne at the apexes a and b; then we can write the reaction v at A, due to a' and b',

$$v = ma' + nb',$$

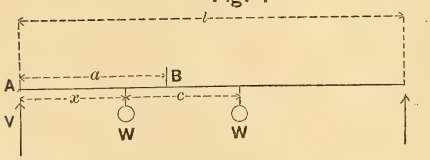
m and n being certain *proper* fractions.

The value of S over the 5th panel, due to the above load, is then, $S_5 = V - a' = nb' - (1-m)a'$, which is *less* than nb'. Now when $x \leqq l, b' \leqq \frac{1}{2}ql \therefore S_5 < nb' \leqq n\frac{1}{2}ql$. But if we suppose (as in art. 18) that the load extends to the middle of the panel, and that the whole of it, $\frac{1}{2}ql$, is concentrated at b; S_5 would be, $n\frac{1}{2}ql$, which is thus always greater than the *actual* shearing force, which we found above to be less than, $n\frac{1}{2}ql$, whether the uniform load covered the whole or a part of the panel ab. The supposition is then on the side of safety.

34. *Chord Strains.*—The live load assumed has been given in art. 16. Let us first ascertain how two weights, each: W=60000 lbs. and c=50 feet apart, are to be placed so as to give maximum strains on any chord panel. Assuming the notation in Fig. 4, we have,

$$V = \frac{2\,W\,(l - x - \frac{1}{2}c)}{l}$$

Fig. 4



whence the amount at any point B, *between* the two weights is,

$$M = Va - W(a - x)$$
$$= W\left\{\left(a - \frac{ca}{l}\right) + \left(1 - \frac{2a}{l}\right)x\right\}$$

Now if the two engines can get on the truss $\frac{c}{l} < 1 \therefore \left(a - \frac{ca}{l}\right)$ is positive. We must suppose $a < \frac{1}{2}l$, for one-half of the truss will be subjected to the same maximum strains as the other half, hence we need only consider one-half. It follows that $\left(1 - \frac{2a}{l}\right) > 1$, hence M increases with x; so that for $x = a$, *or when the front engine is at the section* B, M *is a maximum for that section.* When $x > a$, V is less than before, and hence $M = V'a$ is less than for the maximum just found.

Fig. 5

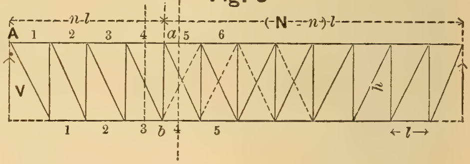


Fig. 6

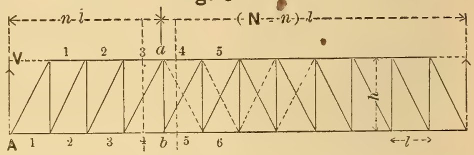
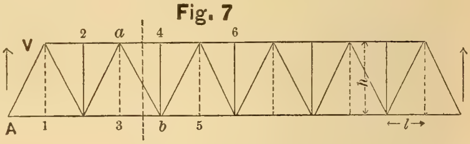


Fig. 7



35. *For a truss, one weight* W *is on the same vertical with the apex taken as the center of moments,* corresponding to B of Fig. 4, *the other weight, c=50 feet, from it on the side of the farthest abutment.*

For *center chord panels*, $a + \frac{1}{2}l \therefore M = \left(a - \frac{ca}{l}\right)W$; which is independent of x; so that the weights, 50 feet apart, can be placed in any position provided they are not both on one side of the center panel.

36. Let N=number of panels (12 in Figs. 5, 6 and 7.

h=height of truss, center to center of chords.

P=uniform load per panel $= w + p$ (art. 18).

E, c, l, as defined in art. 18.

f_n = strain on nth panel of lower chord,

c_n = strain on nth panel of upper chord,

the chords being numbered as in Figs. 5, 6 *and* 7.

It is immaterial whether the loads be considered as concentrated at upper or lower apices or both; hence the results are true whether the trusses are "through" or "deck." First consider the effect of the uniform load alone. For maximum chord strains, the car load must cover the whole truss, since any part of it causes an *upward* moment, giving compression in the upper chord, and tension in the lower one.

Conceive the truss cut in two, as per dotted line, through the panels marked 4 (Figs. 5, 6 and 7) of upper chord, and the right part of the truss removed, and apply as in art. 7 forces equal and opposed to the *resistances* of the cut pieces of the left part. The algebraic sum of the moments of these forces V, and the loads *about any point* must be zero (art. 5). Suppose the counters (dotted lines Figs. 5 and 6) removed, if any should be cut, and *take the center of moments at the intersection of the web member and either chord* to find the strain on the panel of the other chord piece cut. The moment of the web member and chord passing through center of moments is thus zero. This is a general method applicable to any structure and conduces to simplicity.

Thus if the nth (=4th in the Figures) panel of the upper chord is cut, take b as the *center of moments*, b being the intersection of the web member cut with lower chord. Then $c_n h$=moment of c_n; Vnl=moment of V, and $(n-1)P\frac{1}{2}nl$= moment of the $(n-1)$ apex loads, P between A and b, the lower arm of their resultant being $\frac{1}{2}nl$, since they are symmetrically disposed with respect to a point half way between A and b. We have then (art. 5), since $V=(N-1)\frac{P}{2}$,

$$c_n h = Vnl-(n-1)P\tfrac{1}{2}nl$$
$$=[(N-1)n-(n-1)n]\frac{Pl}{2}$$
$$\therefore\ c_n = \frac{(N-n)n}{2h}Pl$$

By giving any value to n, we find c_n corresponding.

37. Next, suppose section taken across panel 4=n say of lower chord (Figs. 5 and 6); the center of moment is then at a, vertically above b; therefore as above we find

$$f_n = \frac{(N-n)n}{2h}Pl$$

the same value as for panel n of upper chord, as it should be; since V, and the loads P, have the same lever arms as before.

The same formulæ apply to fig. 7; only n must have successively the values 1, 3, 5 . . . for the lower chord and 2, 4, 6 . . . for the upper, since the center of moments for any chord panel is at the apex opposite on the other chord, thus giving a uniform strain on two chord panel lengths in turn, as marked in Fig. 7.

38. *Locomotive Excess.*—By art. 35 we suppose $\frac{E}{2}$ placed at a or b (Figs. 5 and 6) and $\frac{E}{2}$, 50=c feet to right, to get the chord strains on panels four upper and lower chords, since a or b is the center of moments corresponding to panels four as marked. The distance from a or b to A being nl, the *reaction* at A of E is (art. 19), $\frac{E}{Nl}[Nl-(nl+c)]$; its lever arm about a or b is nl, so that the moment on the nth panel of upper or lower chord as marked, due to E is,

$$M=\frac{E}{Nl}[Nl-(nl+c)]nl=\frac{E}{N}\left(N-\frac{c}{l}-n\right)nl$$

For Fig. 7 the same formula holds, as is easily seen, taking care to give n the values marked on the chords in turn. Thus $\frac{E}{2}$ is at b to find max. c_4 and at a to find max. t_3. The value of c_n or t_n due to E is therefore

$$\frac{E}{N}\left(N-\frac{c}{l}-n\right)\frac{nl}{h}$$

39. Combining this with the value previously found due to the uniform load we have as the maximum strain that can come on a chord panel, n, as numbered in Figs. 5, 6 and 7

$$c_n = t_n =$$
$$\left(\frac{Pl}{2h}(N-n)+\frac{El}{Nh}\left(N-\frac{c}{l}-n\right)\right)n \quad . \quad (6)$$

40. *Example.*—As in art. 21, let span $=200$ feet, $N=12$, $l=\frac{50}{3}$, $P=w+p=14000+16666=30666$, $E=60000$ lbs., $\frac{c}{e}=1\frac{1}{2}$ and assume the height of truss at twenty-eight feet.

Eq. (6) becomes then

$$c_n = t_n = [9127(12-n)+2976(10\tfrac{1}{2}-n)]n$$

By making n successively, 1, 2, 3, 4, 5, 6, we form the following table: The second differences are constant, as before, thus checking the work.

	$t=c$	Δ_1	Δ_2
$c_1=t_1=(100397+28272)1=$	128669	104463	—
c_2 " t_2 " (91270+25296)2 "	233132	80257	24206
c_3 " t_3 " (82143+22320)3 "	313389	56051	24206
c_4 " t_4 " (73016+19344)4 "	369440	31845	24206
c_5 " t_5 " (63889+16368)5 "	401285	7639	24206
c_6 " t_6 " (54762+13392)6 "	408924	—	—

41. The first and second terms in the ( ) are computed by the common differences, 9127 and 2976.

Thus, in a few minutes time, the chords are accurately calculated for their maximum strains. The strains on the triangular truss Fig. 7 are, as before explained, for the upper chord c_2, c_4 and c_6 respectively; for the lower chord t_1, t_3, t_5. In Fig. 5 the greatest strain on any lower chord panel is, t_6. In Fig. 6 the greatest strain on any upper chord panel is c_5; the strains on the other half of the truss being similar to those of the first half.

The strains thus far found may be marked on larger drawings than those given on the corresponding parts. Let us tabulate the results thus far found in the following table *for truss, Fig.* 7. The length of a diagonal $=\sqrt{28^2+(16\frac{2}{3})^2}=32.6$; and $sec.\ i=\frac{32.6}{28}=1.165$. Multiplying the values S_1, S_2 . . . art. 21, by 1.165 we get the strains on the inch members given in the column marked "Strain"; the *numeration* for the web members being the same as on Fig. 3, as given for the corresponding shearing forces. Thus S_1 *sec.* i=strain on end brace, S_3 *sec.* i for the next *brace* over panel 3, S_5 *sec.* i for next brace over panel 5, S_7 *sec.* i=strain on tie over sixth panel when it acts as a brace, S_8 *sec.* i=strain on brace over fifth panel when it acts as a tie, (see art. 24). The chord strains are designated as in art. 36, Fig. 7.

Column (d) gives the outer diameter in inches of the *compression member*; column $\left(\frac{l}{d}\right)$, the ratio of its length to its diameter; column (th), the thickness of metal in inches; column (θ), the ratio of the *least* strain that can ever come upon a member to the *greatest* strain that can ever come on the member; column (b), the strain for square inch allowed.

The columns headed "Area," "Length," "No." give respectively, the area of the cross section of the member in square inches, its length and the number of pieces similarly strained in two trusses.

Column (k) gives the weight of wrought iron of section one square inch, and one foot long$=\frac{10}{3}$ pounds.

The next column gives the "weight" of member or members in pounds, found by multiplying together the four previous columns.

The last column is a summary, giving the weights on computed strains, in order, of braces and posts, upper chord, main and counter ties, and lower chord, on two trusses.

Column (b) will be explained further on.

42. Given the "strain," and b=safe strain per square inch allowed, $\frac{\text{strain}}{b}$=area, which is put in "area" column. The least section of a post allowed was nine inches, for the vertical posts, that simply sustain one panel of upper chord and bracing. The counter brace was supposed a latticed member. Its total area is that due to its acting both as a strut and main tie (6). The counter tie (8) is supposed enclosed in brace (5). The main braces and upper chords were assumed to be "Phœnix columns."

Piece.	d	$\frac{l}{d}$	th.	Strain.	θ	b	Area.	Len'th	No.	k	Weight.	Totals.
	″		″								lbs.	
Brace 1...........	$13\frac{1}{16}$	30	$\frac{21}{16}$	251766	.36	5340	47.15	32.6	4	$\frac{10}{3}$	20495	
3...........	"	"	$\frac{15}{16}$	173538	.27	4990	34.8	"	"	"	15126	
5...........	"	"	$\frac{11}{16}$	101779	0	3930	25.9	"	"	"	11258	
*Counter 7........	"	"	$\frac{1}{2}$	36487	0	3440	10.6	"	"	"	4607	
Laticing & Angles											4000	
Vertical Posts.....	6	56	$\frac{1}{3}$	2500	1.	280	9.	28.	10	"	8400	63886
Upper Chord c_2...	$13\frac{1}{3}$	15	$\frac{2}{3}$	233132	.39	9050	25.76	$\frac{100}{3}$	4	"	11450	
c_4...	"	"	1	369440	"	9270	39.85	$\frac{100}{3}$	"	"	17711	
c_6...	"	"	$\frac{7}{6}$	408924	"	9270	44.11	$\frac{100}{6}$	"	"	9802	38963
Main Tie 2........				211844	.32	9900	21.4	32.6	"	"	9300	
4........				136850	.16	8700	15.73	32.6	"	"	6836	
6........				68325	0	7500	9.11	32.6	"	"	3960	
Counter 8.........				6268	0	7500	2.	32.6	"	"	880	
Suspenders........				45000	.13	8470	5.3	28.	12	"	5936	26912
Lower Chord 1....				128669	.39	10420	12.35	$\frac{100}{3}$	4	"	5488	
3....				313389	"	10420	30.1	"	"	"	13376	
5....				401285	"	10420	38.51	"	"	"	17120	35984

* Total area tie 6 and counter 7=9.1+10.6=19.7, requiring for a rectangular cross section 3 plates, $13\frac{1}{16} \times \frac{1}{2}$. Under side half latticed bars, $2'' \times \frac{3}{8}''$. Angle irons at 4 corners, $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{3}{8}''$.

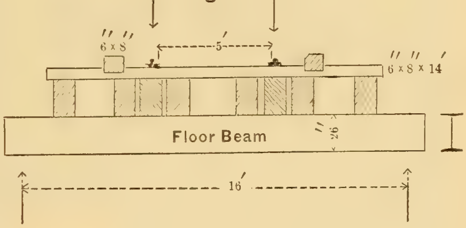
43. Fig. 8 is a section of flooring. The rails, spikes, chains, &c., are assumed to weigh 42 lbs. per foot. Assume the weight of a cubic foot of white pine timber at 36 lbs.; and the cross ties $1\frac{1}{2}$ feet from center to center. Then the weight of cross ties and guard timbers (placed parallel to and on the outside of the rails) per longitudinal foot is $6 \times 8 (14 + 1\frac{1}{2})\frac{2}{3} \cdot \frac{36}{144} = 124$ lbs.

In art. 15, we found the maximum center live load on the *stringers* of a $16\frac{2}{3}'$ panel to be 44987 lbs. The dead load of rails, cross-ties, &c.$=(42+124)\frac{50}{3}$. Assume that stringers weigh 325 lbs. per foot. Then the equivalent center load of one panel of rails, &c., and stringers is, $\frac{1}{4}491 \times \frac{50}{3} = 4092$, making the total center load on stringer, 49080 lbs. If we add 50 per cent. to this to allow for impact, &c., and take 1000 lbs. as the safe strain for pine, we find that we must have 6 stringers under the rails of $9\frac{1}{3}'' \times 20''$ cross section. The 8 stringers will thus weigh 365 lbs. per foot of rail.

4 *Iron stringers* will weigh 300 lbs. per foot (two under the rails) if their depth is 26 inches; neglecting the influence of the web $\frac{3}{8}''$ thick, which is about equivalent to the loss in the rivet holes in the tension flange. The method of computation is the same as for the floor beam.

44. The *Floor Beam*, also the floor

Fig. 8



beam loops sustain a max. live load of 77492 lbs. (art. 15). To this add say 3000 lbs., weight of floor beam, and $531 \times \frac{50}{3} = 8850$ lbs. for stringers, rails, &c.; giving a total load, say on the rails over the floor beam of $(77492+11850) = 89342$ lbs., or 44671 lbs. on each rail. The moment at the center is, $44671 (8-2\frac{1}{2}) = 245690$ *foot lbs.* $= 2,948,280$ *inch lbs.*, which must equal the resisting moment, $fda = 7500 \times 26 \times 15.1$, of the I section ($f$=safe strain=7500 lbs. per square inch, d=26=total depth and a= area of one flange=15.1 square inch). The *cross section*, assuming a thickness of web of $\frac{1}{2}''$, the depth between flanges being 24 inches, is $30.2+8=38.2$ square inch; giving the weight of one floor beam$=38.2 \times 17\frac{1}{2} \times \frac{10}{3} = 2228$ lbs. Therefore 11 floor beams weigh 24500 lbs. The floor beam loops are put at 5000 lbs.

For such depths of beams (26″), it is advisable to diminish the depth of girder from near the center towards the points

of support (see Boller's "Iron Highway Bridges," p. 64), both for economy of beams and loops as well as for appearance sake. The saving so effected will be assumed approximately equal to weight of rivets and stiffeners; which is sufficiently correct for the purposes of these estimates.

45. We are now enabled to find the maximum load on the suspenders of Fig. 7; thus,

Live load on one floor beam....	77492	lbs.
Dead load of floor beam.......	2228	"
Stringers, rails, &c. $(300+166)\frac{100}{6}=$	7770	"
One panel lower chord, &c.....	2000	"
	89490	"

Or, say, 45,000 pounds borne by the suspenders of one panel of one truss.

46. Assuming a wind surface, when the bridge is covered with cars, 16′ high $\times$ 200′ long; the intensity of the wind being taken at 30 pounds per square foot, the uniform horizontal pressure per panel is $16\times\frac{50}{3}\times 30=8000$ pounds $=w$. The trusses are connected between the chords by bracing similar to that of the Pratt truss, Fig. 5 at the center; hence, the sheaving stress, occasioned in this transverse bracing by the wind pressure is given by Eq. (5), on making p and E zero, and $w=8000$. The strain on any member then, is,

$$S_n \sec. i=\tfrac{1}{2}(N-2n+1)\ w \sec. i$$
$$=4000\ (13-2n)\ \sec. i.$$

Allowing for tension 1500, and for compression 5000, pounds per square inch, the rods will average two or three square inches cross section; and their total weight, including bolts, nuts, etc., is put at 5400 pounds. The cross struts and portals are assumed to weigh 6000 pounds.

47. It will suffice, for our purposes, to add twenty per cent. to the computed material in upper chord and posts for castings, etc.; and fifteen per cent. to weight of ties and lower chord for bolts, nuts, eyes and pins; which allowances I find given by Mr. C. Shaler Smith in his "Comparative Analysis of the Fink, Murphy, Bolman and Triangular Trusses" Baltimore, 1870.

From the foregoing data we form the following :

BILL OF MATERIALS.

Triangular Truss—200′ span—28′ high.

Braces and Posts............	63866	lbs.
Upper Chord...............	33693	"
20 per cent. on two last......	20570	"
Main Ties and suspenders ...	26912	"
Lower chord................	35984	"
15 per cent. on two last......	9434	"
Floor beam loops	5000	"
Lateral Bracing.............	11400	"
11 Iron floor beams..........	24500	"
Iron Stringers	60000	"
Rails and Cross Ties.........	33200	"
Total weight.............	329849	"
Assumed weight..........	336000	"
Assumed weight too great by	6151	"

The bridge weight assumed, 336,000 pounds, is, consequently, too great by 6151 pounds.

49. The above allowances for castings, connections, etc., are intended as averages common to several trusses that will be examined. These details are varied indefinitely by builders. All the steps have been given, however, to render adaptation to any particular design easy.

50. In the table, art. 42, we assumed "d"$=13\frac{1}{2}''$ for upper chord. If we put $d=12$ for upper chord and braces, the total weight of bridge is found to be 6340 lbs. greater than before. If we assume that the increased weight of castings, rollers, pins, &c., is not over 2000 to 3000 lbs., there is of course economy in employing the greater diameter; and it may be found economical to increase it still further; taking care that a proper thickness of metal is maintained, say not less than $\frac{1}{3}$ inch.

It is hardly necessary to remark that from the "area" and "d" columns, we can find the inner diameter d_1 and hence the thickness of metal. Thus $\frac{\pi}{4}(d^2-d_1^2)$ $=$ "area," from which d_1 is obtained and $\frac{d-d_1}{2}=$ thickness of metal.

The Moose Mine, in Colorado, situated nearly on the highest point of the South Park range, is probably the highest mine now being worked in the world. The miners' houses are being built into the mountain at the mouth of the mine, considerably over 14,000 feet above the sea.

SPACE OF FOUR DIMENSIONS.

By FREDERICK ZOLLNER.

Translated from the German* for Van Nostrand's Magazine.

We shall consider some of the consequences of our theory when applied to the physical laws of our three-dimensioned phenomenal world. These can be determined only by conclusions analogically drawn from those phenomena which we observe in the projection of three-dimensioned objects upon a plane.

Suppose that we are observing the projection of a scalene triangle in the picture-plane of a camera obscura. If the plane of the triangle is parallel to the picture-plane, the area of the projection is a maximum. If we wish to convert the projection into its symmetrical opposite, the triangle must be turned over. During this operation, alterations take place in all parts of the projection, by which the area is continuously diminished to a minimum, which occurs when the triangle is perpendicular to the plane of projection. With further rotation, the area increases again to its maximum. A being endowed with only the conceptions proper to two-dimensioned space, observing these changes, would of necessity see a contradiction of the axiom of the invariability of the actual quantity of matter contained in a two-dimensioned object. The projection would appear larger or smaller without compensation by any equivalent in the two-dimensional space. Analogous changes would necessarily be observed in our members, and in other bodies if they could be converted into their symmetric opposites. If our bodies were so organized that we could at will convert the right hand into the left, the phenomena of conversion would consist of a gradual diminution, a momentary disappearance, and a re-appearance of the hand. All these phenomena would be miraculous, when considered from the standpoint of our present space-perception; since we should see in them a contradiction of the axiom of the constancy of matter. But this contradiction vanishes from the standpoint of a higher conception of space, when we regard the things of this world as the projections of substantial objects existing in a space of four dimensions. Upon the hypothesis that we could, by our will, effect such transformations of our members, our feelings would convince us of their essentially unchanged condition; as now happens in the case of the varying projections of objects upon our retinae. And in course of time the intuitive conception of a fourth dimension of space would be developed; as has happened by analogous process in the case of a third dimension. In order to comprehend these analogies we must consider that knowledge of all other corporeal properties, as, for example, weight and palpability, is obtained through sensations, just as the knowledge of visible properties is obtained through the eye. Hence the transference of the projection theory to the palpable and the heavy introduces no new principle.

It is well known that the symmetry of space-forms plays an important part in crystallography. It often happens that in a crystal one-half of the plane-system of a simple form is extended by definite laws in such proportion that the other half vanishes entirely. Such crystals are called hemihedric. Both half-surfaces (called sphenoids) of a rhombic octahedron have the same relation as an object to its reflection in a mirror, or as the right to the left hand. According to the projection theory to both these different phenomenal-forms, there is a single correspondent object in four-dimensional space. The observed difference is a consequence of a different position of the object relative to the three-dimensioned region of projection.

There are bodies which are of equivalence in chemical composition, which exhibit different physical and chemical properties. One of the most familiar examples is tartaric and pyroracemic acids. The crystals of sodic-ammonic pyroracemate agree essentially with those of sodic-potassic tartrate. But the former present a remarkable hemihedrism, the octahedric surfaces truncating

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* Extract from an article entitled: *Ueber Wirkungen in die Ferne;* [*Wissenschaftliche Abhandlungen von Friedrich Zöllner Leipzig*].

only one-half of the edge-system; so that reckoning from any determinate truncated surface, such surface appears at the right in certain crystals, while in others it appears at the left.

By the addition of sulphuric acid to a solution of such right-hemihedric crystals right-pyroracemic acid is separated, which is perfectly identical with tartaric acid and which gives no precipitate with a solution of sulphate of lime. A solution of this right pyroracemic turns a perpendicular polarized ray of light to the right. The acid obtained from a solution of left-hemihedric crystals by a like process gives the same reaction as tartaric acid, and gives no precipitate with sulphate of lime, but is optically left-handed. If the right and left acid are mixed in solution, the mixture gives no circular polarization, but throws down a precipitate with sulphate of lime. The crystals of tartaric acid and of right-pyroracemic acid are hemihedric but of direction opposite to that of crystals of left-pyroracemic acid.

These facts furnish an interesting example of the connection of a space-difference in crystals *directly* apprehended, with one that is *indirectly* apprehended by means of chemical and optical appliances which demonstrate a difference in the arrangement of the atoms constituting the bodies. In the latter case there results a presentation to our organism of a difference in quality of matter, similar to the qualitative differences in tone and color which are due to the different lengths of the waves of sound and light.

In a space of four dimensions the right and left hemihedric crystals would appear as species of one and the same object; so would the chemical difference resulting from the molecular grouping of atoms. The change of one crystal form to another, and of one chemical property to another, could be effected by changing the relative position of the four-dimensioned objects; just as we can see the writing on a transparent sheet of paper transformed into its symmetric opposite by looking at it from the opposite side. If there were beings who could, by act of will, transform in a space of four dimensions a substance apprehended by us only indirectly by means of its three-dimensioned projection, so that the space-configuration of its atoms should be changed to the symmetric-opposite, the phenomenon would seem miraculous. For the tartaric acid crystals would seem to be converted into crystals of right-pyroracemic acid, not only in respect to external form, but also in respect to chemical constitution. If we had a four-dimensioned body subject to our will, we should be able to interchange the crystals into various dispositions whose differences would involve some space-meaning; just as happens in the case of differing projections and operations on a three-dimensioned body effected from different standpoints.

If we explain this process of conversion in the symmetric disposition of atoms by attributing them to moving forces, then these must operate in directions which fall in the fourth dimension; that is, in a direction perpendicular to the three-dimensioned region of projection which constitutes our present space. This direction would be represented by a complex space co-ordinate, such as has been employed by Gauss in the interpretation of the imaginary quantity in regions of less manifoldness.

If we regard the distance between two atoms and the intensity of their reactions in our three-dimensional space as the projections of similar magnitudes from a space of four dimensions; then they can alter in magnitude and form and store of potential and kinetic energy of the three-dimensioned projection (our material object) only by altered position relations in the four-dimensioned object.

Hence, the axiom of the conservation of a constant amount of energy holds completely in a space of four dimensions; in fact, it is the premiss, upon which depends the transfer of enlarged conceptions of space to physical processes.

To illustrate: suppose a number of congruent triangles cut from paper to be let fall from a height upon a table. These triangles, which, in a space of three dimensions, would represent identical two-dimensioned crystals, revolve as they fall, and, finally, come to rest upon the table in random positions. Regarding the tangent-plane of the triangles, and the table as the region of two-dimensioned beings, it is obvious, that these beings would recognize among these triangles symmetric but incongruent forms, analogous to our hemihedric

crystals. During the process of rotation, the triangles would, for a time, disappear from sensible space.

With respect to this connection between the chemical properties and the space-relations of the atoms of a body, it is a significant fact, that attention has lately been directed to the meaning of space-moments in the domain of chemistry. In the year 1835, a short memoir was published at Rotterdam, with the title "*La Chimie dans Espace*, by J. H. Van't Hoff, with an introduction by J. Wislicenus, Professor of Chemistry at the University of Würzburg. The latter, speaking of the aim and import of this memoir, says: "That the atoms which are assumed to constitute a molecule must be arranged in some definite space-configuration, and that the same elementary atoms with the same order of succession in their respective composition in complex molecules, may be spatially grouped in different ways, so as to give to structurally identical molecules slight differences in properties, has long been conjectured; and there have been peculiar phenomena which required some such explanation as that which is here indicated. I myself, in my investigations upon Paralactic acid, expressed the opinion that the facts compelled an explanation of the difference of isomeric molecules of the same formula by referring it to the different position of the atoms in space; and that geometric conceptions of the composition of the molecule, must be introduced into chemical theory."

"The fundamental idea of Van't Hoff's theory, lies in the proof that combinations of an atom of carbon with four different simple or compound radicals must always furnish two cases of spatial isomerism."

Again he says: "A simple consideration shows the inadequacy of our so-called modern structural formulas. They represent the molecule, which is of three dimensions, as planar. The discrepancy with the fact involved in this assumption is obvious; and a reform of the prevalent views is to be desired."

"In the case in which the four affinities of a carbon-atom are satisfied by four different groups, our theory leads to a construction of two and only two tetrahedrons, which are incapable of superposition; one of which is the image of the other, and which may be called *enantiomorphic* forms."

The above quotation illustrates the truth of Riemann's assertion that oppositions of thought and of the facts of observation are the conditions by which our knowledge of the world advances. The need and the impulse to push forward the lines of knowledge are always measured by the violence of the paradoxes which we encounter in our experience.

DESCRIPTION OF THE AUBOIS CANAL LOCK, SITUATED ON THE LATERAL CANAL OF THE LOIRE RIVER.

By Prof. WILLIAM WATSON, Ph. D., late U. S. Commissioner.

METHOD OF EMPTYING AND FILLING THE LOCK BY THE PROCESS INVENTED BY THE MARQUIS OF CALIGNY, VIZ., BY MEANS OF OSCILLATING LIQUID COLUMNS; TIME TO FILL OR EMPTY THE LOCK; AMOUNT OF WATER SAVED BY THIS PROCESS; COST.

Process Invented by the Marquis of Caligny.—We know that for each passage through a lock, whether up or down, a quantity of water must be drawn from the upper bay to fill up the lock a height equal to the difference of level between the two bays; this height being called the lift of the lock, and the volume of water required for this purpose, the prism of lift. The system invented by the Marquis of Caligny and applied to the Aubois lock, has for its object to diminish this waste by causing water from the lower bay to ascend into the lock-chamber when the latter is to be filled; and also by making part of the water in the lock-chamber ascend to the fore-bay when the lock-chamber is to be emptied. The system is founded on the known

properties of oscillating liquids, which will presently be explained.

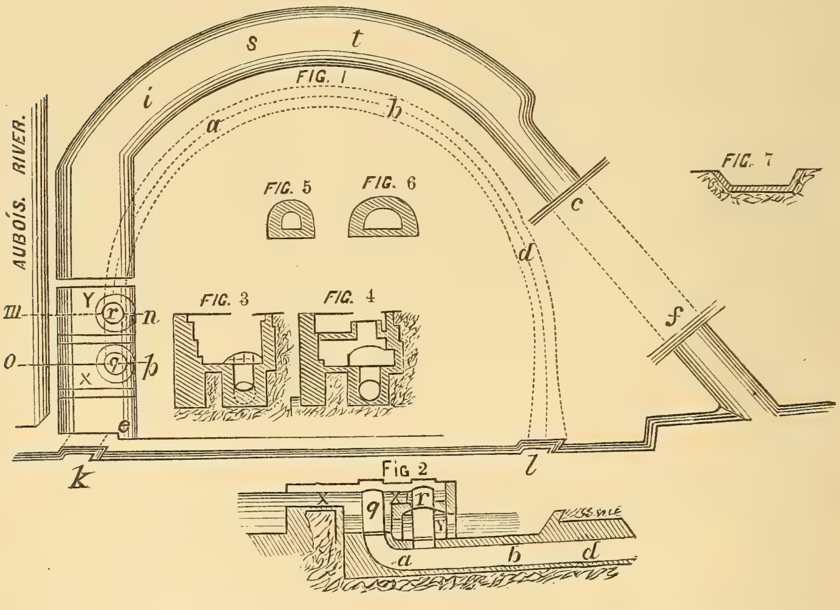
The work consists

1st. (Figs. 1, 2,) of a full-centered aqueduct, *a b d*, 1.20 meters wide, 1.55 meters high under the keystone, and having its bed on a level with the bottom of the lower bay; the depth of the latter being 1.80 meters, the *intrados* of the keystone is 0.25 meter below the level of the lower bay. This aqueduct, which is semicircular between the two heads, empties into the lower gate-chamber, *l*, by an enlarged opening, (Fig. 6,) and on the upper side it connects with two separate reservoirs, X and Y, (Fig. 1) situated behind the upper gate-chamber.

2d. Of a discharging-channel or saving-basin, *i s t*, connecting the reservoir Y with the lower bay by a sluice, (*c*); the other reservoir X communicates with the upper bay.

3d. Of two vertical movable pipes, *q*, *r*, open at both ends, and resting upon two circular openings made in the walls of the aqueduct. One of these pipes is placed in the reservoir communicating with the upper bay, and the other in the one communicating with the lower bay. Both pipes rise 0.10 meter above the level of the upper bay; the lower-bay pipe, *r*, is 1.48 meters in diameter and 3.57 meters high, the upper bay pipe, *q*, is 1.40 meters in diameter and 2.97 meters high. When these pipes are lowered upon their seats, the upper extremity of the aqueduct is shut. If we raise the upper pipe, *q*, the water from the upper bay enters the aqueduct; if, on the contrary, we raise the lower pipe, *r*, the water from the lock goes into the

THE AUBOIS CANAL LOCK.



Explanation.—Fig. 1 represents the lock at Aubois on the lateral canal of the Loire River, *i s t* is the saving basin; *a b d* the underground aqueduct; *k l* the lock; *k* the upper, and *l* the lower gate-chamber.

Fig. 2. The longitudinal section *e q r* of the two reservoirs X and Y, and that of the aqueduct *a b d* with the lifting pipes *q* and *r*.

Figs. 3 and 4. Sections of the reservoirs X and Y made by the planes *o p* and *m n*.

Fig. 5. Section of the aqueduct.

Fig. 6. Section of the aqueduct at *l*, where it discharges into the lower gate-chamber.

Fig. 7. Transverse section of the saving basin.

saving-basin, or *vice versa*, according to their respective levels.

The manner of working is as follows: Suppose the full lock is to be emptied; we raise the pipe *r*, the water from the lock-chamber passes through the aqueduct under the pipe, and enters the saving-basin, which is supposed to be on a level with the lower bay. After having held the pipe *r* raised during a few seconds for the water to acquire its velocity, we drop it back upon its seat; the water in the aqueduct, having no issue under the pipe *r*, rises in the interior of both *r* and *q*, and pours over their tops into the reservoir X, and connected with the upper bay. Thus, on account of the living force of the moving liquid mass in the aqueduct, a part of the water is carried into the upper bay. When this first oscillation has ceased to cause the water to overflow from the pipes *q* and *r*, we recommence the same operation by raising again the pipe *r;* a new column of water issues from the lock; we interrupt again its flow under *r*, and a new oscillation produces a new overflow into the upper bay. As this operation is repeated the lock is emptied, one portion into the saving-basin and thence into the lower bay, another portion into the upper bay. As the difference of level which causes the oscillation diminishes, the height of the oscillation, its duration, and the amount of overflow at each new opening, diminish also; hence, after a time the oscillations become insignificant, as also the water saved by them; at this time we may complete the emptying by opening continuously the pipe *r;* but we may also operate otherwise and produce a new saving. For this purpose we shut the sluice-gate, *c*, between the saving-basin and the lower bay, and raise the pipe *r;* a great oscillation occurs, which causes the water to rise in the saving-basin *above* the level of the lower bay and to fall in the lock below this level; on lowering *r* at the end of this great oscillation we shut into the saving basin a layer of water which will serve for filling the lock, and we have at the same time caused a difference of level between the lock and the lower bay sufficient to make the lower lock-gates open spontaneously. The layer of water obtained at Aubois by this final oscillation is 0.15 meter thick.

If it is required to fill the lock we commence by employing the layer of water stored in the saving basin. For this purpose we raise the pipe *r*, and the water being higher in the basin than in the lock, it enters the latter, producing thereby an oscillation, which causes the level in the lock to be *above* that in the basin, and *lower* in the latter than in the lower bay, so that this first volume introduced into the lock comprises, not only that which has been raised by the previous emptying, but also another portion taken from the saving-basin, *i.e.*, from the lower bay. At the end of this initial oscillation we let fall the pipe *r*, open the sluice *c*, and proceed in another manner. We raise the pipe *q;* the water from the upper bay enters the lock through the aqueduct; at the end of several seconds it has acquired its velocity, then we let fall the pipe *q* and at the same instant raise the pipe *r;* the water in motion in the aqueduct then produces the effect known as *aspiration* upon the water of the saving-basin, which has already been put in communication with the lower bay, and draws it by an oscillation into the lock; so that the volume introduced by this last operation consists of two portions, the first portion being taken from the upper bay to generate the velocity, and the second from the lower bay by utilizing this velocity. At the end of the oscillation we let fall the pipe *r*, raise the pipe *q*, and a new oscillation brings into the lock a new volume; we continue this operation until the diminution of the difference of level between the upper bay and the lock causes the oscillations to become insignificant; from this moment we keep the pipe *q* raised, and thus finish the filling. This prolonged opening produces a final oscillation, by which the water rises in the lock higher than in the upper bay, and opens spontaneously the upper lock-gates.

This canal-lock has been in operation since 1868, and we find

1st. That seven or eight oscillations suffice to fill or empty the lock in five or six minutes.

2d. That for filling the lock without using the reserve in saving-basin, the volume of water taken from the lower bay is 0.41 V, V being the prism of lift, so that the saving by this operation is about two-fifths of V.

3d. That during the process of emptying, the volume sent into the upper bay is about 0.386 V, without considering what is saved by the final oscillation. The sum of the volumes raised by the two operations is $(0.41+0.386)\ V=0.796\ V$. By utilizing the great final oscillations the saving amounts to 0.90 V.

This system of lock, while it economizes the water used, produces neither lowering in short bays, nor exaggerated velocities in the narrow passages; and constitutes an ingenious use of the properties of liquids in motion. Its application to the Aubois lock cost about 40,000 francs, but much of this was owing to the difficulties of position and the nature of the soil which required special precautions. A considerable economy might be made by placing the aqueduct along the side-walls of the lock.

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers.—The annual Convention, beginning June 18th, at Boston, will discuss topics upon which papers have been presented during the year.

In addition to these, it is expected that the following subjects will be presented by papers printed previous to the date of the Convention, or read at its meeting:

Dams across Water Courses. William J. McAlpine.

The rain fall during a storm in October, 1869. James B. Francis.

The law of Tidal Currents. J. H. Striedinger.

The South Pass Jetties; descriptive and incidental notes and memoranda. E. L. Corthell.

Discussion on the preceding paper. Charles W. Howell.

Reminiscences and experiences of early engineering operations on railroads, with especial reference to steep inclines. No. 1, W. Milnor Roberts. No. 2, William J. McAlpine.

Resistances on Railway Curves. S. Whinery.

Notes on the papers in reference to Incline Planes and Resistances on Railway Curves.—Octave Chanute.

Agricultural Drainage. Ed. N. Kirk Talcott.

A graphic method of representing railroad accounts. Charles Latimer.

Science, old and new. Its relation to Engineering. W. Milnor Roberts.

The Mississippi River.—B. M. Harrod.

Brick Arches for Large Sewers. R. Hering.

Improvement of Galveston Harbor (2d Paper). Charles W. Howell.

The Flow of Water in Pipes. Charles G. Darrach.

The proper arrangement and ventilation of house drains. Charles E. Fowler.

On a newly discovered relation between the tenacity of metals and their resistance to torsion. R. H. Thurston.

On Gauging Streams. Clemens Herschel.

Meeting of the American Institute of Mining Engineers at Chattanooga.—The business proceedings of the Convention at the first session held on the 22d, consisted of an address by Dr. Sterry Hunt, and the reading of the papers by J. E. Sweet M. E., and R. W. Raymond of the *Engineering and Mining Journal*.

In the afternoon of the same day the Institute visited the works of the Roane Iron Co., the Tennessee Iron & Steel Co., the Chattanooga Iron Co., and the Vulcan Iron and Nail Works: the party then ascended Lookout Mountain.

The programme for the remainder of the week included for Thursday, a trip by steamer to Shellman, a visit to the Dade Coal Mines; return and visit South Pittsburgh, Victoria, ets., and evening session at Chattanooga.

Friday: In Alabama and Georgia iron and coal fields.

Saturday: Return to Chattanooga, and in evening leave for Rockwood.

Sunday: At Rockwood, afterwards returning to Chattanooga or leaving for home.

Engineers' Club of Philadelphia.—At a recent meeting of the Club, Mr. Wm. F. Sellers read an interesting paper on the *Kentucky River Bridge*. The paper was illustrated by large photographs of the structure and by working drawings. The Cincinnati Southern Railway crosses the Kentucky River at a point where several years ago, four stone towers were erected by Mr. Roebling. The structure for which these were intended was never completed. The river at this point is about 300 feet wide, and flows in the bottom of a narrow cañon, about 300 feet deep and 1,300 feet wide. For numerous reasons, a pier in the river was rendered impracticable; so it was decided to use three spans of 375 feet each. These were erected without the use of any false works, which the great height of the bridge, and the swift current of the stream precluded. Though a continuous girder in three spans would have fulfilled all of the conditions necessary during erection, yet the fact that the iron piers would vary in height with the temperature while the cliff abutments would not, made it obligatory that the spans should be so hinged as to permit of this vertical motion of the piers without altering the strains in the truss. It was finally decided to construct the bridge with a central span which may be described as a beam supported near each end, the overhanging portions helping to support the central portion, the piers acting as fulcrums.

The end spans were supported at the shore ends by abutments, and at the other end by the weight of the middle span acting over the piers as levers; the distance from the pier to the contraflexure point being the short arm of the lever. This important point was found by dealing with the truss, panel by panel, and member by member. The truss is $37\frac{1}{2}$ feet deep, 18 feet wide and each span divided into 20 panels of $18\frac{3}{4}$ feet each. All connections between the ties, posts and cords, were made by pins. Those pins which were strained in erection were forced in place by hydraulic pressure and served as rivets, while other pins

were put in loosely. The dimensions of piers and masonry, and the results of the final tests were given, all proving of very great interest.

Dr. Wm. D. Marks called the attention of the Club to some new and interesting drawing instruments.

One of the instruments was of Prof. Mark's own design, being an adaptation of the Marquois rule which enables a draughtsman to shade a cylinder, shaft, &c., with mathematical correctness.

At the last meeting of the Club, Mr. Henry G. Morris made some very interesting remarks in regard to the proposition which Messrs. William Cramp & Sons have made to the Philadelphia Water Department. They propose to furnish steam pumping machinery and foundations, boilers and air vessel complete, with all valves and attachments, inside the house, to the pumping mains proposed to connect with the distributing pipes of the Belmont Water Works, on the east side of the Schuylkill river, and operate the same.

They also propose to furnish all coal, stores and supplies, provide attendants and maintain repairs free of all charges to the city in the first cost and operating expenses, for the same sum per million of gallons pumped, as it now costs at the Belmont Works, that being the lowest cost, in the list for steam pumpage.

At the expiration of five years from the time the machinery is started, it shall become the property of the City of Philadelphia without further cost or expense: ground and houses to be furnished by the City and located at the Schuylkill Works, the Department to so arrange its pipes that any excess of pumpage not required on the East side can flow into the Belmont Basin, in order that continuous pumpage can be maintained. The machinery to be capable of pumping fourteen millions of gallons per twenty-four hours, the quantity of water pumped to be determined by the method now used by the Department, and payments to be made quarterly on quantities certified by the Chief of the Department.

The cost at the Belmont Works, the cheapest of any of the works in the City, for pumping 1,000 000 gallons 200 feet high, was, in 1877, $14.12. The Messrs. Cramp have stated that they are satisfied that by using their own engines, they can supply the 14,000,000 gallons every twenty-four hours at the same rate as now done at the Belmont Works, $ 14.12 and still make a good profit.

Mr. Morris gave an estimate of the cost at which the work could be done, and by comparison with the duty of the Lowell engines showed approximately what profits might be expected. At Lowell, Mass., the cost was, in 1877, $10.71 per million gallons, for raising water into Reservoir, a height of 166 feet with the Morris engine.

Gen'l. Herman Haupt made very interesting remarks in regard to the Seaboard Pipe Line. About two years ago the Penna Transportation Company called upon General Haupt for estimates in regard to cost of transporting oil to the seaboard by means of pipes. The first pipes in the oil regions for the transportation of oil were laid fourteen or fifteen years ago. At present there are some 2,000 miles of pipe in operation between the wells and the railroads.

At first the Pipe line Co's. met with a very determined opposition from the teamsters and boatmen, but after waging a bitter war against the new system they had to succumb, and pipe lines became the only mode for conveying oil from place to place. The Legislature passed an Act allowing pipe lines in four or five of the Western counties. The Conduit line was started to operate between the oil regions and Pittsburg. After a sharp contest with the Pennsylvania Railroad it succeeded in getting across the line of the railroad by using a public road. The oil was received in tanks which were mounted on wheels, hauled across the railroad, pointed into receivers, and went on its way to Pittsburg. Even with this extra expense of handling the line paid well.

Upon visiting the oil regions it was found impossible to get satisfactory data for formulating the hydraulic pressure and making necessary calculations for an estimate of cost for a long line. The seaboard line propose to use a six-inch pipe which will give a capacity of 6,000 barrels discharge per day, the line will be tested to 1800 pounds pressure per square inch, and worked at 400 pounds per square inch. Preliminary surveys have already been made. The first station will be located at Parker City, from which the oil will be forced a distance of thirty-five miles: the second pump will force it twenty-six miles further: the third pump seventy miles further: and the last pump which will be located on the West side of Tuscarora Mountain will send it to Baltimore a distance of 102 miles. The pressure at each station will be 400 pounds, equal to a head of 1200 feet of oil. Distances between stations varying with the profile of the ground crossed.

The estimated cost of transportation is one cent per barrel at each pump, the distance between pumps being immaterial. Five cents per barrel is a full estimate of cost for transportation from the oil regions to the seaboard. A six-inch line of pipe can be made at a cost of $ 8,000 per mile, making the total cost of the projected line $ 1,750,000. Construction of the seaboard line will be commenced in two or three works.

One of the most important points in the construction of pipe lines is to allow for contraction and expansion due to changes of temperature.

A pipe line is certainly the most economical and natural method for transporting fluids, and there is no more reason why oil transported in pipes should be exported than when transported in cars.

After transaction of business the Club adjourned, to meet October 5th, 1878.

Institution of Mechanical Engineers.—The second meeting of the members of this Institution was held recently at the Institution of Civil Engineers, Great George Street, Westminster. Mr. Boyd read his paper on "Experiments relative to Steel Boilers." Various test experiments on marine steel boilers were described in this paper, and the conclusions de-

duced were that (1) steel plates can now be obtained in which absolute practical uniformity can be relied on, extending over a large quantity of material; (2) that the material is seriously injured or crippled to the extent of something like 33 % by punching, if the clearance given between the punch and the die be about $\frac{1}{16}$th inch, which is usual in good boiler-making work; (3) the injury or crippling of the material does not amount to any appreciable quantity if the holes are drilled; (4) the nature or quality of the material is practically restored entirely if the plates are properly annealed; (5) that it is desirable that all holes in the construction of a steel boiler should be drilled rather than punched; and (6) that, owing to the early tendency to buckle in steel plates, special care is necessary in staying flat surfaces, especially where the plates are thin.

Dr. Siemens said the first news he had of this application of the Landore steel was unfortunate, for the steel had entirely failed to stand the test. Mr. Boyd had now stated the circumstances under which this apparent failure arose. A test plate had been fastened between two bars of iron, and when the tensile strength was applied, the steel, instead of elongating 20 or 25 per cent., as was expected, and then breaking across the rivets, broke through the fastening along a line of fracture. 30 or 35 per cent. longer than the fracture of least resistance. He suggested that the cause of failure would probably be found to lie in the mode in which the fastening had been made. Mild steel yielded very much before rupture of the tensile strain was applied fairly over the whole section, and this made it necessary that it should be fastened along the whole line of its section. In the particular fastening referred so, two large rivets show forward, and naturally would take nearly the whole of the strain, while the other four rivets stood back to such an extent, that before they would receive any considerable portion of the strain, the two forward rivets would be loaded to such an extent as to cause a partial yielding of the metal, and, being near the edge, tearing action would set in. Many people advocated the use of iron rivets for riveting mild steel plates, but he could not too strongly argue against that practice. It was utterly against nature to stretch material like mild steel, together with iron, which behaved quite differently as to elongation and yielding faculty. He was glad to see Mr. Boyd had adopted steel rivets. He did not agree that punching necessarily diminished the strength of a steel plate something like thirty-three per cent. He found by experiment that in squaring a punched hole the strength of the metal was entirely restored, showing that the cause of weakness was in the immediate vicinity of the hole, and did not extend any depth into the metal. The addition of nuts to the stays showed a remarkable increase of strength, and he hoped that mode of staying would be adopted. It was a question whether for flat stay plates this very mild steel should be used; it would probably be more advantageous to use steel containing, perhaps, $\frac{4}{10}$ths of carbon. He had lately witnessed some experiments at Swindon with a view of bursting a steel boiler. The results showed that it was impossible to do so, the boiler might swell and be racked at the joints so as to produce leakage, but that would prevent any further accumulation of pressure.

IRON AND STEEL NOTES.

Preservation of Iron.—The process of preserving iron by means of a coating of its own oxide, recently introduced by Professor Barff, is one which gives such excellent results that we are somewhat surprised at having heard little or nothing of it since its discussion at more than one scientific meeting. There are other workers, too, in the same direction, one of whom, Mr. George Bower, of St. Neots, has shown us a number of specimens of his work. These yield nothing in appearance to the samples of Professor Barff, and their protective coating is fully equal in efficiency, since it is identical in chemical composition. The process by which they are prepared is the outcome of a most elaborate and costly series of experiments, which have been carried out at Mr. Bower's works in St. Neots. It may be explained in a few words to consist in exposing the iron at a suitably elevated temperature to the action of the oxygen of the air. This action forms a coating of the oxide known to chemists as magnetic oxide of iron, which is incapable of change under any ordinary conditions, and which forms on the surface a harder and more coherent film than can be obtained by any other means. Professor Barff, as our readers know, utilized the well-known fact of steam being decomposed in presence of red hot iron; hydrogen being set free and a coating of magnetic oxide of iron formed on the surface of the iron, thus: $Fe_3+4H_2O=Fe_3O_4+4H_2$. It has not, however, been generally known that free oxygen, as it exists in the atmosphere, is also capable of coating under suitable conditions, the surface of the iron with the same oxide as that yielded by steam. To Mr. Bower is due the credit not only of satisfactorily eliciting this important fact, but also of its industrial application. The advantages that air must possess over steam are almost too obvious to require enumeration, and from an economical point of view alone the process deserves every encouragement.

The coating given by the use of air, although permanent and lasting, is of peculiar beauty, and of a greyish or neutral tint, so that for many purposes the necessity of further ornamentation by painting, &c., is dispensed with. The coating has been tested under the severest conditions, and has always resisted most completely all attempts to set up rusting. It should also be mentioned that although the iron may rust at spots from which the magnetic oxide has been removed, the rusting is confined to those spots, the lateral rusting which makes the use of paints, &c., objectionable, not taking place to even the slightest extent.

The method adopted in carrying out this process is to place the articles in a chamber, which is capable of being completely closed, and gradually raise the temperature to the

requisite degree, ranging between a dull and a bright red heat, according to the ultimate use to which the articles may be applied. Air is then passed in, and the chamber completely closed for one hour, when the inlet and outlet pipes are again opened and a fresh supply of air sent into the chamber, which is again closed. This renewal of the air at the end of every hour is continued until the required thicknesses of magnetic oxide is formed on the iron. The air is supplied from a gasholder, or else by connecting the outlet pipe with the draught of the chimney shaft in connection with the furnace heating the chamber. The process is found to answer particularly well for cast iron, but with a slight modification, which is now being worked out, it answers equally well for every other description of the metal.—*Iron.*

The Pig Iron Production of the United States.—Statistics have been published by the American Iron and Steel Association, from which it appears that the grand total for 1877 was 2,314,585 tons of two thousand pounds, against 2,093,236 tons in 1876, a gain of 221,349 tons. Twenty-two States made pig iron in 1877. As compared with other years immediately before and since the panic, the production of 1877 shows a decided reaction from extreme depression, but still falls far short of the country's best achievements. The figures are as follows:—1872, 2,854,558 net tons; 1873, 2,868,278 tons; 1874, 2,689,413 tons; 1875, 2,266,581 tons; 1876, 2,093,236 tons; 1877, 2,314,585 tons. The production in 1877 was about 50,000 tons greater than in 1875. The year 1876, the Centennial year, was the year of greatest depression, and 1873 was the year of greatest production. Of the total production of pig iron in 1877, 1,061,945 net tons were bituminous coal and coke, 934,797 tons were anthracite, and 317,843 tons were charcoal. In 1873, the year of greatest production, the proportions were as follows: Anthracite, 1,312,754 net tons; bituminous coal and coke, 977,904 tons; charcoal, 577,620 tons. It will be seen that, while the production of anthracite and charcoal pig iron has largely fallen off, that of bituminous coal and coke pig iron has very materially increased. The whole number of furnaces in the United States which were completed and either in blast or ready to be put in blast at the close of 1877 was 716, against 712 at the close of 1876. Of the furnaces completed at the close of 1876, 236, or less than one-third, were then in blast, and 476 were out of blast. At the close of 1877 there were 270 in blast and 446 out of blast, showing an increase in that year as compared with 1876 of thirty-four active furnaces.

RAILWAY NOTES.

Some time ago reference was made in this column to a statement of the chairman of the East India Railway Company, that the average mileage of their engines during the previous half year was 1250 miles per month, which he believed exceeded that of any other railway in the world. This the *Railway Age* retorted was not at all an extraordinary mileage, citing among others the case of an engine on the Atlantic and Great Western Road, which made in one month 3681 miles. A correspondent of that journal, and master mechanic of the Cleveland, Tuscaroras Valley and Wheeling Road, writing recently, says: "Passenger engine No. 11 on this road in 1877 made 51,395 miles, making in one month 5640 miles, and engine No. 10 made 48,125 miles, both in passenger service. The first cost 11.26 cents and the second 11.70 cents per mile run. I think that perhaps this is among the greatest mileage made by engines in one year." This is considered a remarkable record, the first engine making an average during the entire year of 165 miles per day, excluding Sundays, and in one month averaging 216 miles per day, counting twenty-six working days to the month.—*Engineer.*

A paper was lately read before the United Service Institution by Mr. J. L. Haddan, C.E., on "Pioneer and Military Railways." A section of a military post and rail or pioneer railway was built on the ground lying waste at the rear of Whitehall Place, to show the simplicity of the work, its constructors being ten soldiers from the Grenadier Guards and two laborers. The railway was primarily designed by the author of the paper to meet the need in the East of a speedily constructed, cheap and effective means of transport for men and stores over a wild country without the necessity of surveying, leveling and passing through the preliminary stages of ordinary railway making. The section built recently in the grounds of Whitehall is a "one central rail" structure with two light side guide rails, the line running upon seven feet posts, 440 to the mile, the rolling stock upon it being designed upon the "camel saddle" principle. The carriages and engines fall on each side like panniers on an animal's back, the wheels of the engines, trucks, and carriages being horizontal and gripping the guide rails. The material of the railway is wholly of timbers brought on the ground ready cut for use, and the plans having been explained to the sergeants of the fatigue party, the piles were sunk in the ground, the cross timbers fixed and bolted, and by a series of wedges an 80 feet or 100 feet section of the line, running over very uneven ground, is made secure, the wedges taking up any slack in the struts. In the discussion which followed the reading of the paper, Sir Garnet Wolseley speaking of the railway in the Crimea, said that "though that was not a great success, it was very useful, and by making it the English nation was the first to use railways in war. The great thing in regard to railways used in war was that they should be quickly made and worked, for time was everything. If we had to go to war and to operate inland in a country where there were no roads, it would be of the greatest importance to have a line from the base of the scene of operations; and Mr. Haddan's proposals gave a system which would meet the requirements of an army in that position. As to particular railways which had been proposed for army transports, in these

days of short and sharp campaigns, earthworks were out of the question, for now armies did not sit down to long campaigns like the sieges of Troy and Sebastopol. Other systems required good roads, but for a country without the roads, and in rapidity and simplicity of construction, Mr. Haddan's railway would meet an army's wants."—*Engineer.*

On the Continent the adoption of steam tramway engines instead of horses is becoming very general. Rouen, Cassell, Barcelona, Bilbao, Lisbon, Oporto, the Hague, and other important towns are all following the example set by Paris, which has working in its streets, engines which are noiseless, smokeless, and free from any objectionable features calculated to obstruct or in any way interfere with the ordinary traffic. As shown in the reports of tramway companies and the remarks of the chairmen at the annual meetings, the proprietors are fully alive to the importance of the subject, and are strongly inclined to take the necessary steps to replace horses by mechanical power. But as public opinion had to be educated in the first instance as regards the tramway itself, so also must it be enlightened respecting the traction; meantime, nothing will be gained by forcing legislation. No one doubts that the use of steam traction in the streets is not remote, but there is no question that before introducing it into the metropolis, provincial towns, and country districts waiting to be thus opened up, offer, in the first instance, the widest and most encouraging scope for its application. As feeders to existing railway lines, and as branches connecting agricultural areas with the centers of commerce from which they are at present excluded, steam-worked tramways will be a most important and industrial aid.—*Engineering.*

ENGINEERING STRUCTURES.

Long Span Railway Bridges.—At the meeting of the Institution of Civil Engineers, held on Tuesday, the 21st of May, the paper read was on "The Design generally of Iron Bridges of very large Spans for Railway Traffic," by Mr. T. C. Clarke, M. Inst. C.E., of Philadelphia.

Since the year 1863, when a paper on the subject was presented by the late Mr. Zerah Colburn, no communication had been submitted to the Institution relative to the construction of iron railway bridges of long spans, as practiced in America. At that time the longest iron span in America was the central tube of the Victoria Bridge at Montreal, 330 feet in the clear. Since then, several bridges had been built with wider openings; and one had lately been completed over the Ohio River at Cincinnati, with a clear span of 515 feet. This was the longest railway girder yet constructed, the next longest, the Kuilenburg Bridge, in Holland, being 492 feet. The arches of the Saint Louis Bridge were also 515 feet span. Almost all American bridges of spans exceeding 100 feet were pin-connected, instead of being united by riveting. That plan was preferred on account of the mathematical certainty with which the strains could be calculated, and the deflection or camber ascertained—of the economy, ease, and celerity of erection, which for rivers subject to sudden floods was a matter of vital importance—and because it was believed that the parts of a bridge could be more strongly united than by riveting, and that a considerable reduction was possible in the dead weight of iron.

Two of the latest and best examples of American long span iron bridge constructions were chosen for illustration. One was the trussed girder bridge across the Ohio River at Cincinnati for the Southern Railway—515 feet between the bearings, and erected on temporary stagings of timber—designed and executed by Mr. J. H. Linville. The other was the bridge of three spans of 375 feet each, carrying the same railway across the Kentucky River, the engineer, in this case, being Mr. C. Shaler Smith. Both bridges were noteworthy for their economical design, and for their comparatively small amount of dead weight.

The Ohio Bridge consisted entirely of rolled iron, pin connected. The girders were quadrangular, each $51\frac{1}{2}$ feet deep, the panels being $25\frac{3}{4}$ feet long, and the girders 20 feet apart from center to center. The weight of iron in the span of 515 feet was 1176 tons. With a total load of 431 tons, the center deflection of the east truss was $2\frac{3}{32}$ inch, with a permanent set of $\frac{1}{16}$ inch, that of the west truss being 2 inch, with no permanent set.

Advantage was taken by the engineer of the Kentucky River Bridge, of two towers and sets of anchorage, formerly constructed for a suspension bridge across the canon, which had not been completed. The first panel of this bridge on each side was bolted to the towers, and was then corbelled out panel by panel. The towers were calculated to be strong enough to carry 196 feet of projecting spans. At this point the spans were supported by temporary towers of wood. The corbelling out process was continued until the above spans each reached the main iron piers, which were built up simultaneously, so that the two met in mid air. Each half of the center span was then corbelled out as before, until they met in the center. At this stage of the work, the upper chords being in tension and the lower in compression, the former were nearer to each other than the latter by a few inches. The method of closing the gaps under the changes resulting from alterations of temperature was then described. Up to this time the bridge was a girder 1125 feet long, continuous over three spans. But while the abutments on the cliffs were stationary, the iron piers rose and fell under changes of temperature, and so varied the strains on the web system. The shore spans were therefore hinged at points 75 feet from the piers, leaving a center girder 525 feet long, supported by piers 375 feet apart. Both of the web systems of diagonal rods were consolidated into one member at the point of contrary flexure, and were separated again after the hinge was passed. When the bridge was tested it was found that the movement of the lower chord tenons under the passing load was $1\frac{1}{2}$ inch. Every effort was made to secure

the uniformity of the modulus of elasticity of every part of the ironwork. Nevertheless, the variation in length, between the east and west chords, was 1 inch in 1125 feet. When the end spans were loaded with 277 tons, and the center span unloaded, the central deflection was 1.52 inch, and the upward movement of the central span was 2.83 inch. With the center span loaded with 331 tons, and the end spans unloaded, the central deflection was 3.5 inch, and the upward movement of the cantilever was 1.58 inch. With all the spans loaded, 814 tons in 904 feet, the center deflection of the center span was 1.62 inch. The Kentucky River Bridge occupied four months and four days in erection, the average number of workmen employed being fifty-three. The average cost of erection was about £2 10s. per ton. The weight of iron in the bridge was 3,654,271 lbs. The depth of the truss was 37½ feet, and its width was 18 feet. The iron pier at the base was 28 feet by 71½ feet; at the top it was 1 foot by 18 feet; and it was 177¼ feet high. This was one of the boldest and most original pieces of bridge engineering in America. Both it and the Ohio River Bridge were conspicuous for economy of design. Economy of design was obtained by proportioning all the parts of a bridge with a similar factor of safety, and then combining those parts into a whole; and, secondly, by using such proportions of height of girder, length of panel, and combination of parts; also, such width apart between the girders, and such methods of bracing the two into a structure able to resist wind pressure or shocks, as would accomplish the first requisite with the least quantity of metal. The problem could only be solved by a tentative process. To show how this had been accomplished, the author gave a table of the weight of iron and other important data of some of the most conspicuous long span railway bridges constructed in Europe and America, and contrasted several of the examples cited. Finally, the author stated that the workmanship of long span bridges in the United States was generally first class; and that the price of American bridgework had fallen year by year, from £40 6s. per ton in 1870 to £20 16s. per ton in 1877.

ORDNANCE AND NAVAL.

Torpedo Cases.—A train passed through London recently conveying 100 wrought iron cases from Newcastle to Woolwich. These were torpedoes, each to contain 500 pounds to 1000 pounds of gun-cotton, and when they have had a coat of red paint they will be placed in the torpedo stores at Woolwich Dockyard, where there are at the present time torpedoes by the thousand, of all sizes ready for issue—the stores, notwithstanding the recent demands upon them, being almost full. The new torpedoes have been manufactured by Sir William Armstrong at his Elswick factory under a contract entered into only a few weeks since, and they were delivered last night on one of the new platforms of the branch line running into the dockyard. As most of the contracts entered into on the strength of the £6,000,000 are terminable at the 31st of March, the deliveries grow in number and quantity as the month advances.

Gun Carriages.—The Royal Carriage Department is still very busy with all kinds of work, among which are a number of carriages for the 64-pounder guns on the well-known Moncrieff counter-balance principle. Twenty-five of these carriages are in the estimate for the current year, and it is intended to employ them in the coast defences. A number of the Moncrieff carriages of larger pattern for the 7-inch gun were manufactured several years ago, and are in use at various home stations, chiefly in Ireland and on the river Severn. When elevated to deliver its fire the gun surmounts a 5-feet 6-inch parapet, the recoil of discharge bringing it down under cover for reloading. The pneumatic principle for elevating guns required for overbank fire at siege works is at present making but little progress, a readier system of elevating the gun on a carriage having been adopted in view of emergencies.

Utilization of Discarded Breech-Loaders.—There are a number of 7-inch breech-loading guns in store at the Royal Arsenal, Woolwich, having been for several years discarded in favor of more modern weapons, but attempts are now being made to utilize them. By chambering the gun and the use of pebble power, which is comparatively mild in its action, it has been found possible to fire much heavier charges than originally proposed; but there is no expectation of making the guns do the work of the 7-inch armor-piercing muzzle-loaders. The latter, however, weighs 7 tons, and is 11 feet ten inches in length, while the breech-loader weighs but 82 cwt. and has a length of 10 feet. Colonel Heyman, Royal Artillery, proposes to mount the resuscitated gun on an ordinary wooden platform fitted with hydraulic buffers, and the service in which it will be employed is the defence of positions where a battery fire is not required.

Another Addition to the British Navy.—The Brazilian Government has got rid of a marine white elephant, and our Admiralty has made another considerable hole in the historic "six millions" by the transfer of the powerful armor-clad vessel *Independencia* from the Brazilian to the British flag. After spending between £600,000 and £700,000 on her construction the Brazilians have come to the conclusion that the game is scarcely worth the candle, and that smaller vessels would better serve all purposes in South American waters. The vessel in question was commenced in the Thames yard of Messrs. Dudgeon, after the designs of Mr. Reed, in 1872, and launched in October, 1876. She is of 9000 tons displacement, with engines indicating 1200, but working up 8000 horse-power. She is provided with a very prominent gun-metal stem, forming a ram, and her dimensions are 300 feet length between the perpendiculars, 63 feet extreme breadth, and 50 feet height. The armor plating is 12 inches thick at the water-line, and from 9 to 10 inches in other parts. The arma-

ment consists at present of four 35-ton breech-loading Whitworth guns, placed in two turrets protected by 13 inches of armor.

THAMES TORPEDOES.—The torpedo arrangements in connection with the Thames defences are now complete. The station is at Shornemead battery. The buildings erected consist of magazine, connecting shed, cable tanks, stores, &c. A jetty has been constructed on piles and carried some distance into the river, far enough to enable the torpedo launches to embark or disembark at any time of the tide. The whole arrangement has been carried out under the direction of Colonel E. M. Grain, commanding Royal Engineers at Gravesend. The torpedoes will be moored, when required, in various parts of the river, sinkers being attached to them. Each torpedo so laid down will be connected by an electric cable with one of a series of bells, so that upon a ship touching a torpedo it will be instantly known in the operating room, and, as the torpedoes are exploded from the shore, it will be at the discretion of the officer in charge either to blow the ship out of the water or let her pass on her course. There will not be the slightest danger to the ordinary road traffic, as the torpedoes can only be fired by completing the electric circuit, and this can only be done by the officers on shore.

BREECH-LOADING ARTILLERY.—Although artillerists still strongly favor muzzle loading guns, it seems to have been determined to gratify the advocates of breech-loaders by a new course of experiments, and three guns are being prepared at the Royal Gun Factories in the Royal Arsenal, Woolwich, for the purpose. One is an ordinary 32-pounder smooth-bore gun, which is being converted into a breech-loader on the French or screw-relieve system, the thread of the screw being cut away in such a manner that one-sixth of a turn releases it. This gun being cast iron will not be rifled, and it will fire only low charges and smooth-bore projectiles—probably case shot alone. The second experimental gun is one of the old 40-pounder Armstrongs, already a breech-loader, but the wedge which at presents lifts out at the top will be constructed to slide out at the side. The third gun is an Armstrong 64-pounder, which is to be converted into a double-wedge gun after the pattern of Krupp's German guns. While these guns are being prepared a trial is being made at Woolwich with a large breech-loader manufactured by Sir William Armstrong at Elswick, and submitted for experiment. It weighs about 70 cwt., and is bored and rifled for a 6-inch projectile. The gun is fitted with the French breech system for purposes of investigation.—*Iron.*

A COLLAPSING BOAT.—Another trial of one of Mr. Berthon's twenty-eighth feet collapsing boats, designed for use in troop-ships, was made in the steam basin, Portsmouth, on the 17th inst., in the presence of Rear-Admiral Foley, Mr. W. B. Robinson, Chief Constructor, Mr. J. Elliot, Constructor, and the inventor. Sixty blue-jackets and a coxswain were placed on board, three pinnaces being in attendance to pick them up should anything untoward occur. The weight brought the boat down about a foot in the water, leaving twenty inches of freeboard to spare, and under these conditions she was rowed around the basin with apparent ease. But, although there was no collapsing of the side, as in the previous experiment, the boat, when subsequently examined by Mr. Elliot, showed so many unmistakable signs of distress and structural weakness as would have probably proved fatal in a seaway. The defect was again found to consist in the arrangement of the diagonal shores which extend from the foot battens to the under part of the gunwales or covering board, and which serve the purpose of keeping the boat spread out when actually in use. The shores are jointed in the middle in order to allow the boat to collapse, lashings being placed around the joints and secured to an eye fixed in one of the longitudinal frames, and others around the points of the lappings for the purpose of keeping the shores straight and the boat in form. Under the strain to which it was subjected it was found that the batten against the toe of the shores had been forced out of its fore-and-aft direction, and in one place broken, and that the gunwale, which is formed of several breadths bolted together, had opened and been bent. As in a seaway the strains would have been frequently localized, it seemed clear to the officers that a collapse was only prevented by the still water in which the trial was made. —*Iron.*

BOOK NOTICES

PINE PLANTATIONS ON THE SAND WASTES OF FRANCE. Compiled by JOHN CROUMBIE BROWN, LL.D. Edinburgh: Oliver & Boyd.

The interest in Forest culture is rapidly increasing in this country. It is only recently that the public voice has been raised against the useless destruction of woods already in growth. Soon we shall hear of efforts to raise extensive forests in sections where none have grown before. The benefits of such tree culture are manifold and lasting. In these matters we naturally depend for advice of people of older countries in which this industry has been successfully pursued.

No writer within our knowledge has studied the subject so widely as Dr. BROWN, and no one else presents so much information that is valuable to tree culturists of the United States.

The present work is especially of this latter kind.

THE JOURNAL OF FORESTRY AND ESTATES MANAGEMENT. London: J. & W. Rider. Subscriptions received by D. Van Nostrand. Price $6 00 a year.

The June number of this excellent journal is at hand. Every issue presents something of interest and value for tree growers in this country.

In the absence of an American periodical devoted to this practical science, we can recommend this journal to those of our readers who are interested in forest protection or in forest culture.

La Methode Graphique dans la Sciences Experimentales. Par E. J. Marey. Paris: G. Masson. For sale by D. Van Nostrand. Price $6.40.

This is a large octavo of 660 pages, presenting a collection of the various methods for representing graphically the action of different forces.

The phenomena treated belong chiefly to the department of physiology. Some of the methods are new; most of them are not.

Some of the devices for registering the action of the heart, and for measuring the force of its action are very ingenious.

The work is beautifully printed and illustrated with 348 wood cuts.

Traite Theorique et Pratique de la Fabrication du Sucre. Par E. J. Maumene. Tome II. Paris: Demod. For sale by D. Van Nostrand. Price $12.00.

The volume completing this extensive work treats of the chemistry and physiology of all plants employed in manufacture of sugar, the culture of saccharine plants, the manufacture of sugar, the sugar mills and the refining processes, covering eight hundred pages of text, and illustrated by 140 excellent wood cuts.

But few manufacturing processes are so fully and ably treated, as is the manufacture of sugar in this treatise of Maumené.

Proceedings of the Institution of Civil Engineers.

Through the kindness of Mr. James Forrest, Secretary of the Institution, we are in receipt of the following papers:

Liquid Fuels. By Harrison Aydon.

Evaporative power of Locomotive Boilers. By Atkinson Longridge, M. I. C. E.

Recent Improvements in Electro-Dynamic Apparatus. By R. W. H. P. Higgs, and J. R. Brittle.

The first is illustrated with extraordinary fullness.

In a future number we will present extracts from the above papers.

The War Ships of Europe. By Chief-Engineer King, United States Navy. Portsmouth: Griffin & Co. London: Simpkin, Marshall & Co. For sale by D. Van Nostrand. Price $4.25.

This is virtually a reprint of a Report upon European Ships of War, made by the author to the Secretary of the Navy at Washington, in 1877, and the information given is of great value to all professional men, as well as to the general public. Construction, cost, and speed are considered, the advantages one ship has over another is explained, and the strong and weak points of each are pointed out. It appears that in the eight years (1866–74) our expenditures on shipbuilding and repairs amounted to £15,666,155. The repairs during the above period are returned at the sum of £5,164,475, for both ironclads and unarmored vessels. In the years 1866–67 the repairs to ironclads cost £109,145, but in 1873–74 the outlay had risen to £291,381. The expenditure on unarmored ships on the same account was, in 1866–67, £782,728, and in 1873–74, £464,911. What will be most interesting to readers at the present time, is the review of foreign naval resources, though the bulk of the work is taken up with our own. All the Naval Powers are made to furnish materials for the work. The book is amply illustrated, a sheet of diagrams of targets fired at by the 100-ton gun, being among the excellent plates given. The work has the value attaching to it of being the testimony of a thoroughly independent critic. Though the book is especially adapted to naval men, the general public will find it extremely interesting.—*Iron.*

The Road Master's Assistant and Section Master's Guide. By William S. Huntington Revised and enlarged by Chas. Latimer. New York: Railroad Gazette. For sale by D. Van Nostrand. Price $1.50.

This improved edition of a useful book will, we trust, be well received. The additions have been made by a skillful and experienced hand in railway construction.

The information afforded in the treatise is given in a direct and concise way that will be appreciated by the class of learners for whom it is designed. Although technical in its character, the subject matter of the book is frequently a topic of absorbing interest to the non-technical citizen. The question of greater or less excellence in railway construction, involving as it does the degree of safety in railway travel, demands, at times, the close attention of people who are neither Road Masters nor Section Masters.

Boiler and Factory Chimneys. By Robert Wilson, A.I.C.E. London: Crosby Lockwood and Co. For sale by D. Van Nostrand. Price $1.50.

This is a useful little work by a gentleman who is in the habit of thinking out his subject before he ventures into print. To many persons it may appear that the building of a chimney for a boiler furnace is a mere question of good bricklaying, but, as a matter of fact, many important questions must be decided before the bricklayer can be set to work. The height and the area of the chimney will depend primarily on the number and kind of boilers employed, but several other factors must be considered if a really satisfactory result is desired, not excluding the prevailing direction of the wind and the general atmospheric temperature of the district. When the size of the chimney has been determined, its shape and the form of the cap require study, and then last, but not least, its stability must be seriously considered. All these points are examined by Mr. Wilson, who also writes a chapter on lightning conductors, and gives us some interesting figures in connection with notable chimneys. The highest known chimney is that at Mr. Townshend's Works, Port Dundas, which, with the exception of the spire at Strasburg, the Great Pyramid, and the spire of St. Stephen's, Vienna, is the loftiest building in the world, rising to a height of 454 feet from the ground, the total height of the brickwork, &c., being 468 feet. This book forms an excellent supplement or complement to the author's "Treatise on Steam Boilers." We

should mention that Mr. Wilson furnishes, by way of frontispiece, a useful table of dimensions of chimneys from 30 feet to 300 feet in height.—*English Mechanic.*

MISCELLANEOUS.

Artificial Stone.—A German patent (we learn from *Ding. Pol. Jo.*) has lately been granted to Dr. Zernikon, of Oderberg, for production of artificial stones by boiling of mixtures of mortar. The chief constituents of the stone's mass, sand and slaked lime, are known to show great resistance to atmospheric influences. By boiling (according to the patentee) a combination of silica and lime takes place; and the hardness of the mortar, petrified by aqueous vapor, even increases by absorption of carbonic acid from the air. The specimen pieces show throughout the hardness of good natural sandstone; they are now about a year old, and must have gained in hardness, for shortly after casting they could still be cut with the knife. Cracks and fissures are nowhere observed, and are hardly to be expected in future, as the combination of lime and sand, under action of hot water, is effected only at such small degress of heat (between 120° and 150°), that a reduction of the lime hydrate to free caustic lime cannot have taken place. As regards the cost of production, the price of the raw materials—80 to 90 per cent. sand, and 10 to 20 per cent. slaked lime—will scarcely be higher than that of clay for bricks. The time of heating is nearly the same in both cases, but the heating for bricks requires nearly a white glow, whereas for the mortar stone it has only to be brought to 150° C.; thus there is considerable saving in fuel. The mode of forming the prism-shaped stones is similar to that of machine made bricks, where they are pressed through a mouthpiece. All expenses of manufacture included, 100k. of the mortar stones, of prismatic shape, cost about two marks.—*English Mechanic.*

The *Austrian Military Review* gives some particulars as to the underground telegraph lines which are being laid from Berlin to the most distant extremities of the German Empire. The first underground line completed was that between Berlin and Halle, which is to be connected with three lines from Berlin to Cologne, from Berlin to Frankfort-on-the-Maine, and from Berlin to Strasburg. The lines from Berlin to Hamburgh and Kiel, from Berlin to Breslau, and from Berlin to Konisburg were then proceeded with. The Berlin-Hamburg line is provided with two parallel cables, each of seven wires; and from Hamburgh one of these cable is continued to Kiel, and the other to Wilhelmshafen and Emden, where it is joined on to the North Sea cable to England. The work of laying these cables is very difficult in mountainous districts, but along the high roads it is simple enough, and of late the operation has been further simplified by the use of a machine constructed for the purpose. This machine, attached to a traction engine, excavates the earth along the line of route, and, having laid the cable in the ground, throws it back again; the only manual labor required being that of the men who level the soil afterwards. This machine was tried in the presence of Herr Stephan, the Director of the Prussian Post Office, upon the underground line from Berlin to Spandau, by way of Charlottenburg, and was found to work very well. Marshal von Moltke has despatched a detachment from one of the "railway regiments" to Spandau to make an underground passage for the cable underneath the fortifications, and a commission composed of civil engineers and telegraph *employés*, has been appointed to arrange for laying down in the course of the spring the lines from Berlin to Cologne, Frankfort, and Strasburg.

Torpedo Defences.—The torpedo defences of the River Thames are now in a perfectly complete and satisfactory condition. A company of Royal Engineers is stationed at Sheerness on torpedo duty at the mouth of the Thames and Medway, and the system of defence is identical with that adopted for the protection of the various seaports, viz., the submersion of stationary mines attached by chains to iron sinkers, connected by electric cable with the shore, where the touch of a ship is instantly registered and whence the torpedo can at once be fired. Bermuda is now defended by a regular system of submarine mines, complete arrangements for the protection of the fort having been planned and carried out since the arrival at the station of the 28th company Royal Engineers from England.

Steel and Wrought Iron Projectiles.—Experiments are to be resumed at Shoeburyness for the purpose of gaining information as to the penetrative power of steel and wrought iron projectiles and the resistance of specially prepared targets. Some of the results already obtained have produced most unexpected and surprising experiences, the most remarkable being found during a trial of a composite steel and iron target. When fired against the steel face of the target, the projectiles broke up badly, but when the target was reversed the shot not only penetrated the softer wrought iron, but went clean through the steel as well. This is theoretically accounted for by the supposition that in passing through the wrought iron the metal of the projectile gets set up into a more compact body, and is therefore better able to endure the shock of the heavier impact. This discovery, if it be a discovery, is to be further investigated, and in order to test it in the opposite direction a steel projectile with a wrought-iron face upon it has been made at the Royal Laboratory Department, Royal Arsenal, Woolwich, and sent to Shoeburyness this week.

The storm flood, which caused such serious damage along the Continental shores of the German Ocean last autumn, has laid bare some remains of the village of Eidum, in the Island of Sylt, on the west coast of Schleswig Holstein, which perished in the year 1436 by the sea suddenly breaking over it and covering it up. Stone foundations of former dwellings, garden walls, and remains of various kinds are now seen there.

VAN NOSTRAND'S

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THE THEORY OF INTERNAL STRESS IN GRAPHICAL STATICS.

By HENRY T. EDDY, C. E., Ph. D., University of Cincinnati.

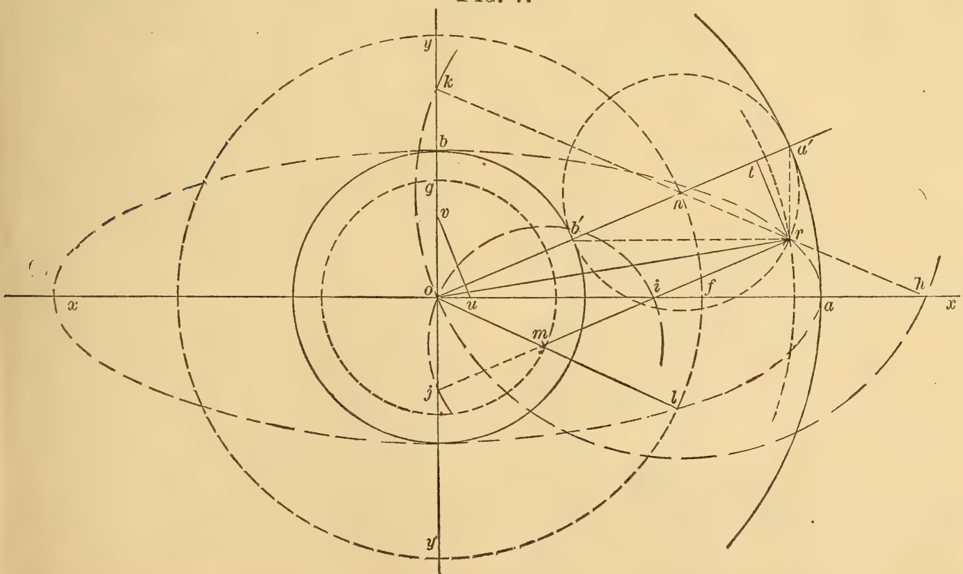
Written for VAN NOSTRAND'S MAGAZINE.

II.

PROBLEMS IN PLANE STRESS.

PROBLEM 1.—When a state of stress is defined by principal stresses which are of unequal intensity and like sign, *i.e.*, in a state of oblique stress, to find the intensity and obliquity of the stress at *o* on any assumed plane in the direction *uv*.

FIG. 7.



In Fig. 7 let the principal stresses at o be a on yy and b on xx; and on some convenient scale of intensities let $oa=a$ and $ob=b$. Let uv show the direction of the plane through o on which we are to find the stress, and make on perpendicular uv. Make $oa'=oa$ and $ob'=ob$. Bisect $a'b'$ at n, then $on=\frac{1}{2}(a+b)$ and $na'=\frac{1}{2}(a-b)$. Make $xol=xon$ and complete the paralellogram $nomr$; then is the diagonal $or=r$ the resultant stress on the given plane in direction and intensity.

The point r can also be obtained more simply by drawing $b'r \parallel xx$ and $a'r \parallel yy$.

We now proceed to show the correctness of the constructions given and to discuss several interesting geometrical properties of the figure which give to it a somewhat complicated appearance, which complexity is, however, quite unnecessary in actual construction, as will be seen hereafter. It has been shown that a state of stress defined by its two principal stresses a and b can be separated into a fluid stress having a normal intensity $\frac{1}{2}(a+b)$ on every plane, and a right shearing stress whose principal stresses are $+\frac{1}{2}(a-b)$ and $-\frac{1}{2}(a-b)$ respectively.

Since the fluid stress causes a normal stress on any given plane, its intensity is rightly represented by $on=\frac{1}{2}(a+b)$, which is the amount of force distributed over one unit of the given plane. Since, further, it was shown that a right shearing stress causes on any plane a stress with an obliquity such that the principal stress bisects the angle between its direction and the normal to the plane, and causes a stress of the same intensity on every plane, we see that $om=\frac{1}{2}(a-b)$ represents, in direction and amount, the force distributed over one unit of the given plane which is due to the right shearing stress.

To find the resultant stress we have only to compound the forces on and om, which give the resultant $or=r$

The obliquity nor is always toward the greater principal stress, which is here assumed to be a.

It is seen that in finding r by this method it is convenient to describe one circle about o with a radius $of=\frac{1}{2}(a+b)$ and another with a radius $og=\frac{1}{2}(a-b)$, after which any parallelogram mn can be readily completed. Let nr and mr intersect xx and yy in hk and ij respectively; then we have the equations of angles,

$$noh=nho=\tfrac{1}{2}kno,\ nok=nko=\tfrac{1}{2}hno,$$

$$moi=mio=\tfrac{1}{2}jmo,\ moj=mjo=\tfrac{1}{2}imo,$$

hence $$hn=kn=on=\tfrac{1}{2}(a+b)$$

$$\therefore\ hk=a+b,$$

and $$rk=rj=a,\ rh=ri=b.$$

It is well known that a fixed point r on a line of constant length as $hk=a+b$, or $ij=a-b$ describes an ellipse, and such an arrangement is called a trammel. If x and y are the coordinates of the point r, it is evident from the figure that $x=a\cos xn$, $y=b\sin xn$, in which xn signifies the angle between xx and the normal on.

$\therefore\ \frac{x^2}{a^2}+\frac{y^2}{b^2}=1$ is the equation of the stress ellipse which is the locus of r; and xn is then the eccentric angle of r. Also, since $noh=nho$, $nb'r=nrb'$; hence $b'r \parallel xx$ and $a'r \parallel yy$ determine r.

In this method of finding r it is convenient to describe circles about o with radii a and b, and from a' and b' where the normal of the given plane intersects them find r.

We shall continue to use the notation employed in this problem, so far as applicable, so that future constructions may be readily compared with this. It will be convenient to speak of the angle xon as xn, nor as nr, etc.

Problem 2.—When a state of stress is defined by principal stresses of unequal intensity and unlike sign, *i.e.* in a state of oblique shearing stress, to find the intensity and obliquity of the stress at o on any assumed plane having the direction uv.

In Fig. 8 the construction is effected according to both the methods detailed in problem 1, and it will be at once apprehended from the identity of notation.

Since a and b are of unlike signs $a+b=on$ is numerically less than $a-b=a'b'$.

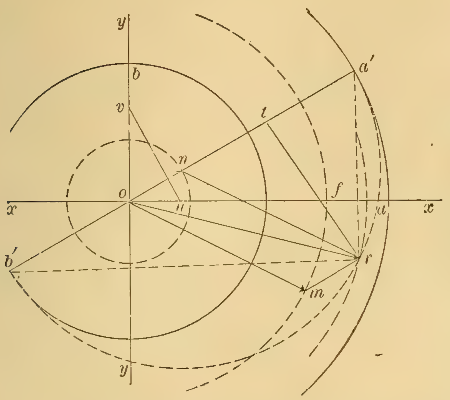
The results of these two problems are expressed algebraically thus:

$$r^2=\tfrac{1}{4}(a+b)^2+\tfrac{1}{4}(a-b)^2+\tfrac{1}{2}(a^2-b^2)\cos 2xn$$

$$\therefore\ r^2=\tfrac{1}{2}[a^2+b^2+(a^2-b^2)\cos 2\,xn]$$

$$\text{or, } r^2=a^2\cos^2 xn+b^2\sin^2 xn.$$

FIG. 8.



If r be resolved into its normal and tangential components $ot=n$ and $rt=t$

then, $n=\frac{1}{2}[a+b+(a-b)\cos 2xn]$,

or, $n=a\cos^2 xn+b\sin^2 xn$,

and,

$t=\frac{1}{2}(a-b)\sin 2xn=(a-b)\sin xn\cos xn$.

It is evident from the value of the normal component n, that the sum of the normal components on any two planes at right angles to each other is the same and its amount is $a+b$: this is also a general property of stress in addition to those previously enumerated.

Also $\tan nr=\frac{t}{n}=\frac{a-b}{a\cot xn+b\tan xn}$

The obliquity nr can also be found from the proportion

$\sin nr : \frac{1}{2}(a-b) :: \sin 2xn : r$.

In the case of fluid stress the equations reduce to the more simple forms:

$$a=b=r=n,\ t=0$$

For right shearing stress they are:

$$a=-b=\pm r,\ n=\pm a\cos rn,$$
$$t=\pm a\sin rn,\qquad rn=2\ xn.$$

And for simple stress they become:

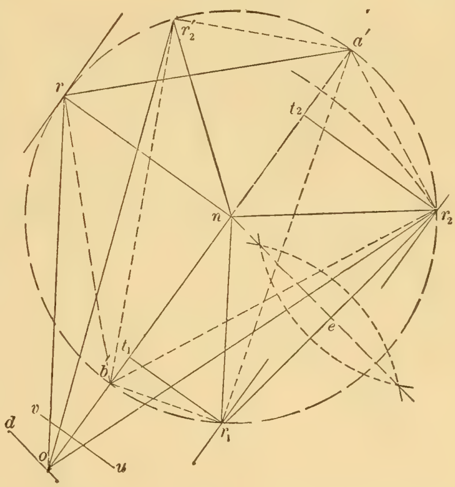
$$b=0,\ r=a\cos rn,\ n=a\cos.^2 rn,$$
$$t=a\sin rn\cos rn,\ rn=xn.$$

PROBLEM 3.—In any state of stress defined by its principal stresses, a and b, to find the obliquity and plane of action of the stress having a given intensity r intermediate between the intensities of the principal stresses.

To find the obliquity nr and the direction uv let Fig. 7 or 8 be constructed as follows: assume the direction uv and its normal on, and proceed to determine the position of the principal axes with respect to it. Lay off $oa'=a$, $ob'=b$, in the same direction if the intensities are of like sign, in opposite directions if unlike. Bisect $a'b'$ at n and on $a'b'$ as a diameter draw the circle $a'rb'$. Also, about o as a center and with a radius $or=r$ draw a circle intersecting that previously drawn at r; then is nr the required obliquity; and $xx \parallel b'r$, $yy \parallel a'r$ are the directions of the principal stresses with respect to the normal on.

PROBLEM 4.—In a state of stress defined by two given obliquities and intensities, to find the principal stresses, and the relative position of their planes of action to each other and to the principal stresses.

FIG. 9.



In Fig. 9 let nr_1, nr_2 be the given obliquities measured from the same normal on, and $or_1=r_1$, $or_2=r_2$ the given intensities. As represented in the figure these intensities are of the same sign, but should they have different signs, it will be necessary to measure one of them from o in the opposite direction, for a change of sign is equivalent to increasing the obliquity by 180°, as was previously shown.

Join r_1r_2 and bisect it by a perpendicular which intersects the common normal at n. About n describe a circle $r_1r_2a'b'$; then $oa'=a$, $ob'=b$, $a'r_1$, $b'r_1$,

are the directions of the principal stresses with respect to r_1 and $b'r_2$, $a'r_2$ with respect to r_2, *i.e.*, $ob'r_1=xn_1$ and $ob'r_2=xn_2$

$$\therefore\ n_1n_2=ob'r_2-ob'r_1=r_2b'r_1=r_2a'r_1$$

In case the given obliquities are of opposite sign, as they must be in conjugate stresses, for example, it is of no consequence in so far as obtaining principal stresses a and b is concerned whether these given obliquities are constructed on the same of on, or on opposite sides of it; for a point on the opposite side of on as r_2' and symmetrically situated with respect to r_2 must lie on the same circle about n. But in case opposite obliquities are on the same side of on we have $n_1n_2=ob'r_1+ob'r_2=r_1b'r_2'$.

It is unnecessary to enter into the proof of the preceding construction as its correctness is sufficiently evident from preceding problems.

The algebraic relationships may be written as follows.

$$\tfrac{1}{4}(a-b)^2=\tfrac{1}{4}(a+b)^2+r_1^{\,2}-r_1(a+b)\cos n_1r_1$$
$$\tfrac{1}{4}(a-b)^2=\tfrac{1}{4}(a+b)+r_2^{\,2}-r^2(a+b)\cos n_2r_2$$
$$\therefore\ (a+b)(r_1\cos n_1r_1-r_2\cos n_2r_2)=r_1^{\,2}-r_2^{\,2}$$

Also $(a-b)\cos 2xn_1+a+b=2r_1\cos n_1r_1$

$(a-b)\cos 2xn_2+a+b=2r_2\cos n_2r_2$

which last equations express twice the respective normal components, and from them the values of xn_1 and xn_2 can be computed.

Problem 5.—If the state of stress be defined by giving the intensity and obliquity of the stress on one plane, and its inclination to the principal stresses, and also the intensity of the stress on a second plane and its inclination to the principal stresses, to find the obliquity of the stress on the second plane, and the magnitude of the principal stresses.

Let the construction in Fig. 9 be effected thus: from the common normal on lay off or, to represent the obliquity and intensity of the stress on the first plane; draw od so that $nod=xn_2-xn_1$ the difference of the given inclinations of the normals of the two planes; through r_1 draw r_1r_2 perpendicular to od; about o as a center describe a circle with radius r_2 the given intensity on the second plane, and let it intersect r_1r_2 at r_2 or r_2', then is nr_2 the required obliquity. This is evident, because

$$xn_1=nb'r_1=\tfrac{1}{2}a'nr_1,\ xn_2=nb'r_2=\tfrac{1}{2}a'nr_2,$$
$$\therefore\ nod=one=\tfrac{1}{2}(onr_1+onr_2)$$
$$=180^\circ-(xn_2-xn_1)$$

If xn_1 and xn_2 are of different sign care must be taken to take their algebraic sum.

The construction is completed as in problem 4.

Problem 6.—In a state of stress defined by two given obliquities and either both of the normal components or both of the tangential components of the intensities, to find the principal stresses and the relative position of the two planes of action.

If the obliquities nr_1, nr_2, and the normal components $ot_1=n_1$, $ot_2=n_2$ are given, draw perpendiculars at t_1 and t_2 intersecting or_1 and or_2 at r_1 and r_2 respectively.

If the tangential components $t_1r_1=t_1$ and $t_2r_2=t_2$ are given instead of the normal components, draw at these distances parallels to on which intersect or_1 or_2 at r_1r_2 respectively. Complete the construction in the same manner as before.

Problem 7.—In a state of stress defined by its principal stresses a and b, to find the positions and obliquities of the stresses on two planes at right angles to each other whose stresses have a given tangential component t.

Fig. 9, slightly changed, will admit of the required construction as follows: lay off on the same normal on, $oa'=a$, $ob'=b$; bisect $a'b'$ at n; erect a perpendicular $ne=t$ to $a'b'$ at n; draw through e a parallel r_1r_2 to on intersecting or_1 and or_2 at r_1 and r_2 respectively. Then the stresses $or_1=r_1$, $or_2=r_2$ have equal tangential components, and as previously shown these belong to planes at right angles to each other provided these tangential components are of opposite sign. So that when we find the position of the planes of action one obliquity, as nr_2, must be taken on the other side of on, as nr_2'. The rest of the construction is the same as that already given.

Problem 8.—In a state of stress defined by its principal stresses, to find the intensities, obliquities and planes of action of the stresses which have maximum tangential components.

In Fig. 9 make $oa'=a$, $ob'=b$ and describe a circle on $a'b'$ as a diameter; then the maximum tangential component is evidently found by drawing a tangent at r parallel to on, in which case $t=a-b$, and rb', ra' the directions of the principal stresses make angles of 45° with on, which may be otherwise stated by saying that the planes of maximum tangential stress bisect the angles between the principal stresses; or conversely the principal stresses bisect the angles between the pair of planes at right angles to each other on which the tangential stress is a maximum.

It is unnecessary to extend further the list of problems involving the relations just employed as they will be readily solved by the reader.

In particular, a given tangential and normal component may replace a given intensity and obliquity on any plane.

We shall now give a few problems which exhibit specially the distinction between states of stress defined by principal stresses of like sign and by principal stresses of unlike sign, (*i.e.* the distinction between oblique stress and oblique shearing stress).

PROBLEM 9.—In a state of stress defined by like principal stresses, to find the inclination of the planes on which the obliquity of the stress is a maximum, to find this maximum obliquity and the intensity.

In Fig. 10 let $oa'=a$, $ob'=b$ the principal stresses; on $a'b'$ as a diameter describe a circle; to it draw the tangent or_0; then nr_0 is the required maximum obliquity and or_0 the required intensity. It is evident from inspection that in the given state of stress there can be no greater obliquity than nr_0. The directions of the principal axes are $b'r_0$, $a'r_0$ as has been before shown.

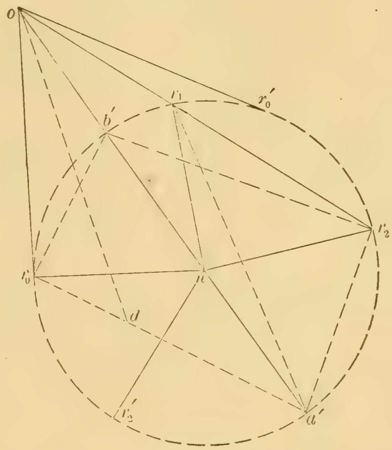
There are two planes of maximum obliquity, and or_0' represents the second; they are situated symmetrically about the principal axes.

Bisect nr_0 by the line od, then

$$oa'r_0=yn \therefore onr_0=2yn, \quad \text{but}$$
$$onr_0+nor_0=90^\circ \text{ or, } 2yn+nr_0=90^\circ$$
$$\therefore \tfrac{1}{2}nr+yn=45^\circ, \quad \text{but}$$
$$odr_0=doa'+oa'd \therefore odr_0=45^\circ,$$

hence the line bisecting the angle of maximum obliquity bisects also the angle between the principal axes. This is the best test for the correctness of the final position of the planes of maximum obliquity with reference to the principal axes.

FIG. 10.



PROBLEM 10.—In a state of stress defined by its maximum obliquity and the intensity at that obliquity, to find the principal stresses.

In Fig. 10 measure the obliquity nr_0 from the normal on and at the extremity of $or_0=r_0$ erect a perpendicular intersecting the normal at n. Then complete the figure as before. The principal axes make angles of 45° at o with od which bisect the obliquity nr.

The algebraic statement of Problems 9 and 10 is:

$$\sin nr_0=\frac{a-b}{a+b}=-\cos 2xn,\ r_0^2=ab.$$

$$r_0=a \cot xn=b \tan xn \quad \therefore \quad a=b \tan^2 xn$$

The normal and tangential components are:

$$n_0=\frac{2r_0^2}{a+b}, \qquad t_0=\frac{r_0(a-b)}{a+b}$$

PROBLEM 11.—When the state of stress is defined by like principal stresses, to find the planes of action and intensities of a pair of conjugate stresses having a given common obliquity less than the maximum.

In Fig. 10 let $nr_1=nr_2$ be the given

obliquity; describe a circle on $a'b'$ as a diameter; then $or_1=r_1$, $or_2=r_2$ are the required intensities. The lines $a'r_1$, $b'r_1$ show the directions of the principal axes with respect to or_1, and $a'r'_2$ $b'r'_2$ with respect to $or_2'=or_2$. The obliquities of conjugate stresses are of opposite sign, and for that reason r_2' is employed for finding the position of the principal stresses. The algebraic expression of these results can be obtained at once from those in Problem 4.

PROBLEM 12.—When the state of stress is defined by the intensities and common obliquity of a pair of like conjugate stresses, to find the principal stresses and maximum obliquity.

This is the case of Problem 4, so far as finding the principal stresses is concerned, and the maximum obliquity is then found by Problem 9. The construction is given in Fig. 10.

PROBLEM 13.—Let the maximum obliquity of a state of oblique stress be given, to find the ratio of the intensities of the pair of conjugate stresses having a given obliquity less than the maximum.

In Fig. 10 let nr_0 be the given maximum obliquity, and $n\,r_1$ the given obliquity of the conjugate stresses. At any convenient point on or_0, as r_0 erect the perpendicular r_0n, and about n (its point of intersection with on) as a center describe a circle with a radius nr_0 which cuts nr_1 at r_1 and r_2; then $or\div or_2=r_1\div r_2$ is the required ratio.

It must be noticed that the scale on which or_1 and or_2 are measured is unknown, for the magnitude of the principal stresses is unknown although their ratio is $ob'\div oa'$. In order to express these results in formulæ, let r represent either of the conjugate stresses, then as previously seen

$$\tfrac{1}{4}(a-b)^2=\tfrac{1}{4}(a+b)^2+r^2-r(a+b)\cos nr$$

$$\therefore\ 2r=(a+b)\cos.\,nr\pm[(a+b)^2\cos^2 nr-4ab]^{\frac{1}{2}}$$

Call the two values of r, r_1 and r_2; and as previously shown $r_0^{\,2}=r_1r_2$; also

$$\cos.\,nr_0=r_0\div\tfrac{1}{2}(a+b)$$

$$\therefore\ \frac{r_1}{r_2}=\frac{\cos nr-(\cos^2 nr-\cos^2 nr_0)^{\frac{1}{2}}}{\cos nr+(\cos^2 nr-\cos^2 nr_0)^{\frac{1}{2}}}$$

When $nr=o$ the ratio becomes

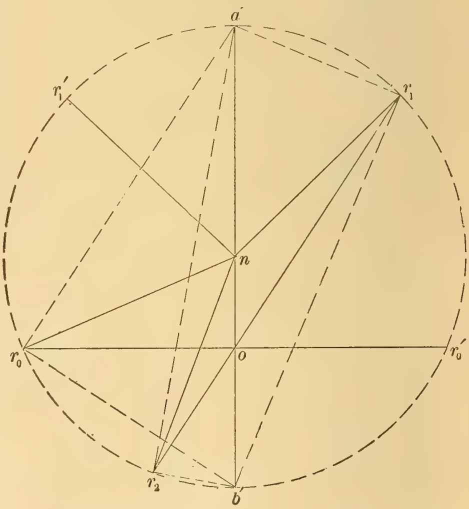
$$\frac{b}{a}=\frac{1-\sin nr_0}{1+\sin.\,nr}$$

PROBLEM 14.—In a state of stress defined by unlike principal stresses, to find the inclination of the planes on which the stress is a shear only and to find its intensity.

In Fig. 11 let $oa'=a$, $ob'=b$, the given principal stresses of unlike sign; on $a'b'$ as a diameter describe a circle; at o erect the perpendicular or_0 cutting the circle at r_0; then is $or_0=r_0$ the required intensity, and $b'r_0$, $a'r_0$ are the directions of the principal stresses.

It is evident from inspection that there is no other position of r_0 except r_0' which will cause the stress to reduce to a shear alone. Hence as previously stated the principal stresses bisect the angles between the planes of shear.

FIG. 11.



PROBLEM 15.—In a state of stress defined by the position of its planes of shear and the common intensity of the stress on these planes, to find the principal stresses.

In Fig. 11 let $or_0=r_0$ the common intensity of the shear, and $or_0b'=xn$, $or_0a'=yn$ the given inclinations of a plane of shear; then $oa'=a$ and $ob'=b$ the principal stresses.

The algebraic statement of Problems

14 and 15, when n_0 denotes the normal to a plane of shear, is:

$$\frac{a+b}{a-b}=-\cos.2xn_0,\ r_0^2=-ab=t_0^2$$

$$r_0=\pm a\cot xn_0=\pm b\tan.xn_0, a=-b\tan^2 xn_0$$

Problem 16.—When the state of stress is defined by unlike principal stresses, to find the planes of action and intensities of a pair of conjugate stresses having any given obliquity.

In Fig. 11 let nr_1 be the common obliquity, $oa'=a$, $ob'=b$ the given principal stresses. On $a'b'$ as a diameter, describe a circle cutting or_1 at r_1 and r_2; then $or_1=r_1$, $or_2=r_2$ are the required intensities. Also, since the obliquities of conjugate stresses are of unlike sign, the lines $r_1'a'$, $r_1'b'$ show the directions of the principal stresses with respect to on_1, and r_2a', r_2b' with respect to on_2.

Problem 17.—When the state of stress is defined by the intensities and common obliquities of unlike conjugate stresses, to find the principal stresses and planes of shear.

In finding the principal stresses this problem is constructed as a case of Problem 4, and then the planes of shear are found by Problem 14. The construction is given in Fig. 11.

Problem 18.—Let the position of the planes of shear be given in a state of oblique shearing stress, to find the ratio of the intensities of a pair of conjugate stresses having any given obliquity.

In Fig. 11 at any convenient point r_0 make $or_0b'=xn$, $or_0a'=yn$ the given angles which fix the position of the planes of shear. On $a'b'$ as a diameter describe a circle; make nr_1 equal to the common obliquity of the conjugate stresses; then is $or_1\div or_2=r_1\div r_2$ the ratio required.

The ratio may be expressed as in Problem 13, and after reducing by the relations

$$r_0^2=-ab,\ r_0\div\tfrac{1}{2}(a+b)=-\tan.2xn_0$$

we have,

$$\frac{r_1}{r_2}=\frac{\cos nr+(\cos^2 nr+\tan^2 2xn_0)^{1/2}}{\cos nr-(\cos^2 nr+\tan^2 2xn_0)^{1/2}}$$

When $nr=o$ the ratio becomes

$$-\frac{a}{b}=\frac{1+\cos 2xn_0}{1-\cos 2xn_0}$$

STREET-CLEANSING IN PARIS.

By M. Vaissiere.

From "Annales des Ponts et Chaussées," Abstracts published for the Institution of Civil Engineers.

The cleansing of the public thoroughfares in Paris, formerly undertaken by the Prefect of Police, is now a function of the Prefect of the Seine. The staff consists of two chief engineers, one for each group of arrondissements, one group being sub-divided into three sections, each under the charge of an executive engineer; and the other into five sections, similarly supervised. These sectional engineers have under them fifty-one superintendents and sixty-one overseers, whose employment imposes upon the municipal budget an annual cost of 260,000 francs. The scavenging plant is kept in a central depot, where materials of every description are stored and classified for ordinary and extraordinary service, when snow and ice render additional assistants necessary.

The depots contain supplies of chloride of lime, sulphate of zinc, sulphate of iron, and carbolic acid, as disinfectants; and hydrochloric acid nitro-benzide (acide de mirbane), as cleansing agents. The chloride of lime, of a strength of 100° to 105°, is successfully employed for the disinfecting of places tainted with urine or fæcal matter, also for the cleansing of gutters carrying sewage water. Sulphate of iron and sulphate of zinc are both used under the same conditions. Sulphate of iron possesses the disadvantage of rusting objects to which it is applied. Sulphate of zinc is stronger in its action, but costs a little more. It pro-

duces no smell, nor does it leave any trace. It is much employed in summer for washing and watering the basements of the Halles Centrales, used for fish, poultry, and offal. At a strength of $\frac{1}{8}$, and mixed with three per cent. of sulphate of copper, sulphate of zinc makes a good disinfecting liquor, which preserves its qualities a long time and is of great use in private houses. Carbolic acid is not strictly speaking, a disinfectant; it does not act like chloride on putrid matter, but arrests and prevents fermentation, doubtless by destroying the spores. It is therefore always employed when it is desired to destroy the germs of putrid fermentation. It is used at a strength of about $\frac{1}{40}$, say a gallon of the acid to forty gallons of water. At strengths of $\frac{1}{100}$ and $\frac{1}{200}$ it gives good results for watering once or twice a week in summer those parts of the Halles Centrales liable to infection. It is even used as low as $\frac{1}{1000}$ for watering streets and gutters. Hydrochloric acid is applied to urinals and slaughter-houses. In places much encrusted with tartar it is used at a strength of $\frac{1}{6}$. Lowered to $\frac{1}{10}$ it cleans smooth walls and flags sufficiently. In ordinary rinsings a strength of $\frac{1}{15}$ suffices. It leaves a disagreeable odor behind, which is however quickly dissipated. Mirbanic acid (nitro-benzide) is more energetic than the foregoing, but it produces a disagreeable smell of bitter almonds, and leaves a white film which has to be washed off. It is used at the same strengths as hydrochloric acid. The annual cost for plant and disinfecting materials of all descriptions is £ 8,800 (220,000 francs).

The engineers of the city of Paris are also charged with the sweeping of the roads, an area of 12,916,800 square yards being cleaned between 3 and 6 A.M. in summer and between 4 and 7 in winter. The carts for removing the public and private refuse work from 6 to 8 A.M. in summer and from 7 to 9 in the winter. The filling of each cart is attended to by the driver aided by two shovellers, the latter having to provide during the rest of the day supplemental sweepings wherever required, to rinse the gutters twice a day, and to clear and disinfect urinals, &c. These matters are ordinarily finished by 4 o'clock in the afternoon, except in unfavorable weather. The engineers have all at their disposal a staff of

	fr. c.		fr. c.	
2,200 men at from	2 50	to	4 0	per day.
950 women "	0 20	to	0 25	per day.
30 children (boys) at	0 20			per hour.

In addition there are one hundred and ninety mechanical sweepers, and as each machine represents the effective work of ten men, the total scavenging staff may be considered as composed of nearly five thousand laborers.

The mechanical sweepers which, after numerous trials and much hesitation, have been introduced into Paris are, the English machine, improved by M. Sohy, and the machine of M. Blot, the former being preferred. The mechanism of both is simple, works with regularity, and occupies little space; it consists of a frame-work upon two wheels with a seat for the driver. At the back is placed the sweeping apparatus, composed of an inclined circular bass broom, actuated by gearing driven from one of the wheels of the carriage. By means of a clutch the driver can from his seat easily put the broom in or out of gear. The machine is employed in all weathers, and works as well on paved roads as upon macadam or asphalt. Each machine weighs rather over 14 cwt., and can be drawn by one horse. It sweeps about 6,578 square yards per hour. The cost of a machine is £ 40, and its annual maintenance, exclusive of renewals of the brush, £ 8. The cost of a new brush is about £ 2 16s. (70 francs), which will work for from one hundred and sixty to one hundred and eighty hours.

The Paris mud no longer possesses the manurial strength of former times, and in consequence the receipts derived by the municipality from this source have greatly diminished. It is at present disposed of by public tender to responsible contractors for terms of about four years. For its removal there are daily employed five hundred and twenty carts, and nine hundred and eighty horses. The average bulk removed per day is about 2,223 cubic yards (1,700 cubic meters).

When a fall of snow occurs, attention is first directed to clearing the footpaths and crossings, so as to insure uninter-

rupted circulation of foot-passengers. The town scavengers sand the roads wherever it is necessary for the carriage traffic. At the same time numerous auxiliaries are organized to remove the snow from the principal thoroughfares, in the order of their relative importance. For removing the snow the General Omnibus Company are bound by their concession to furnish fifty wagons, and carts are specially arranged for with the providers of sand and gravel at the beginning of winter, the contractors for maintaining the public roads being also bound to hold their carts at the disposition of the sectional engineers. In certain cases the half-melted snow is swept into the sewers, especially those carrying warm water. Melting by steam has been tried, when a continuous jet was introduced into a mass of banked snow, but it melted very slowly at first, and the melting ceased after the cavity had increased to a certain size. Two descriptions of snow plough are kept in store, one for manual, the other for horse power; but they have never been used, as the coating of snow seldom attains sufficient thickness, and as it is too quickly compressed and hardened by the traffic. As a rule the sum allowed in the budget, about £7,000, suffices for the extra labor incurred; but occasionally severe winters cause this to be greatly exceeded, as in 1875–76, when the increase amounted to £8,000.

Both hose and carts are used for watering the thoroughfares, the former for the boulevards, the avenues, and a certain number of first-class streets. The watering plant belongs to the municipality. Three descriptions of carts are in use, two heavy wooden ones are now being superseded by the third, Sohy's cart, made of sheet iron. The carts contain 220, 242, 286 gallons respectively, and will water from 2,400 to 3,350 square yards. The watering by hose is attended to by the ordinary street cleaners, who can easily water 24,000 square yards in thirty-five minutes, deducting the time necessary to connect the apparatus with the mains. There are three hundred and twenty-two water carts, which on the average disperse 1,311,200 gallons of water over a surface of 7,139,163 square yards. A surface of 2,783,092 square yards is watered by hose, and this system is being greatly developed on account of its convenience and cheapness. The annual cost of watering is £18,000.

IRON AND STEEL FOR SHIPBUILDING, &c.

By W. W. KIDDLE, A. I. C. E.

From "Nautical Magazine."

It is a common saying that we live in an age of progress, yet it may well be doubted if advantage is fully taken of all the great resources which nature has pre-eminently conferred on Great Britain. Not long since the whole country was drifting into a self-complacency which has severely injured trade, by unsettling the minds of the majority of the working classes as to the nature of the principles which govern it. They appeared to think that when prices were forced up by combination to an unnatural level the results were to stand forever. But the rude shocks of competition and its consequent results, have awakened Englishmen to the fact that other countries can successfully mine the coal, and smelt the iron, and make huge castings, and ply the loom, to an extent which at one time seemed impossible. In defiance of what trade delegates may hold forth or workmen affect to believe, foreign manufactures are gradually supplanting many which at one time appeared to have exclusively taken root in English soil. Many great political economists also affect to see no danger to our mercantile supremacy in this flooding of the markets of the world with the produce of our rivals, and speak of the absence of capital as an insurmountable barrier to their progress. Capital is the child of labor, and where there are willing hands and

good security it will find a resting place and fructify, as it ever does, under such favorable circumstances; while, like the sensitive plant of Central America, it instinctively closes up at the approach of danger. Holland has created capital out of the sand dunes of the German Ocean, the beds of morasses, and even the bottom of her lakes, until individually she is one of the richest countries in Europe. With such evidence, can there be a doubt of the ability of more favored nations to follow a similar path. At no remote period a foreign flag was not often seen in any of the great commercial ports of India, China, or the West Indies; yet at this moment they have nearly the whole of the heavy goods trade, and no inconsiderable portion of more valued freights. The steam fleets of Hamburgh and Bremen may now be met in America and the Spanish Main, bidding for freights which were formerly carried exclusively in English bottoms. One of the great staples—tobacco—is almost monopolized by a German line. We all remember the witticisms which were launched against the first attempts of Germany to become a Naval power. *Punch* is silent now, and finds other subjects for caricaturing. It would add to his fame if he were wiser in his conceits, for the perseverance of a race which is not to be daunted by failure, has already made its mark on an element upon which Englishmen, until recent times, imagined they had no rivals. This has been accomplished under disadvantages which might well have made a more favorably placed people pause, as their limited coast in the bight of the North Sea is full of shoals, is low, is destitute of good harbors, and is on a dead leeshore, with all the prevailing winds. At one time no undertaking ever offered a less chance of success. It is now completed—ships, crews, and harbors—and in a few years the new creation will become an important factor in European complications. Such a result proves that modern science, backed by an indomitable will, can dispense with accumulations of capital until it can be exacted from conquered states, a proceeding which the plundered will neither forget nor forgive. The most fatal weakness which can come over individuals or nations is the undervaluing of an enemy, and it is one from which England has suffered in a pre-eminent degree in recent times. It caused the loss of the thirteen colonies, the capture or destruction of several men-of-war on a subsequent occasion, the Indian Mutiny, and many other disasters of a similar nature. May she take warning from the past and regulate her conduct accordingly in the future.

In arts and manufactures the same indifference has begotten competition, which has seriously affected the staple industries of the country, and it is to be regretted that a large portion of the injury has arisen from causes which the merchant princes of the last generation would have scorned to entertain. The Hindoo, after washing his highly-sized cloth in the waters of the Ganges, does not recognize it as the same material which a few minutes before was apparently thick and glossy. The African, as he looks at his shattered hand and broken gun-barrel, or, when face to face with the wild beasts of the forest, finds his powder will not send a bullet into the head of the elephant or the buffalo, curses the dishonest trader to whose rapacity he may probably owe the loss of his limbs or his life. If enormous capital be absolutely necessary before commercial enterprises can succeed, how comes it to pass that America can produce rifles and send them to Constantinople at a price which this country cannot compete with? How comes it to pass that the artillery of the great armies on the Continent and the heavy rifled guns on the shores of the Bosphorus, the Baltic, and the Mediterranean should be the work of German forges, while not a single order has reached this country since the commencement of the Russo-Turkish war? It would be idle to say that this arose from a regard of the neutrality laws, or even from a higher principle; the love of gain rises superior to either. How comes it to pass that the locomotives from the factories of the United States are scaling the Andes, or running on the plains of Peru, when the roads on which they ply are the offspring of English capital? How comes it to pass that the iron castings and bar iron of Belgium are constantly finding their way into the seats of English trade, and underselling rivals on their chosen ground? Instances might be multiplied

but there are unmistakeable indications that every year the struggle for the custom of the world will become more intense, and the results more uncertain, unless the masters and working men of England resolve to work together and redeem a prestige which has been rudely shaken by recent events.

To aid this great work, the genius of the engineer is absolutely necessary, in order to more fully develop the hidden powers which nature only yields to patient research, and to make them serviceable to the uses of man. For centuries the great work has been slowly progressing, but artificial wants have, during recent years, increased to such an extent as to imply that the time has arrived for the advent of one of those great inventions or improvements which mark an age.

For some time the consumption of fuel per horse-power has not sensibly decreased and men have anxiously watched the numerous experiments which have been tried, with feelings akin to those who are aware that the advantages with which they commenced life are slipping from their grasp. To regain that ascendency another start is necessary, and when patient research has developed the means by which one pound of coal will do double its present amount of work, we shall enter on a new phase of prosperity. For the want of this factor, foreign merchant navies have long been gaining on the English as before described. When it is discovered, the cheaply worked sailing ship of the Northmen will disappear as surely as the once famed and much vaunted American liner has before the Cunard and the Inman steamers.

At present, economy in manning and equipment of steam vessels is carried, in many instances, beyond the limits of prudence and safety, therefore retrenchment cannot be made under those headings. Indeed, it is highly probable that the State or the great insurance corporations will, before many years have elapsed, step in and demand legislation on the subject, for life and property alike appear to suffer from its omission, notably in the grain and coasting trades. A steam ship of 1041 tons, recently wrecked, had a crew of deck hands amounting to four all told. In other words, one seaman, one ordinary to work the winches, the carpenter, and a boy. This is an extreme, although not an exceptional case, but it goes to prove that the most elaborate machinery cannot economize any more in that quarter. The only hope of a further reduction of expense now depends on scientific discoveries which may be utilized by practical men, until the whole carrying trade of the country owes its transport to the agency of mechanical power. The days of propulsion by sail can never again be highly remunerative around the shores of the United Kingdom. Men may lament the decay of ancient seamanship, but cannot change the inevitable. They may with equal reason regret the extinction of the Knights of Malta.

It appears singular that with iron in unlimited quantities in so many of the counties in England, so little comparative progress is made to utilize it. In this particular we are far behind the United States, although their command of every species of timber for building purposes is far in advance of that of the United Kingdom. In all the principal cities and towns the rafters, the shop fronts, and fittings of every description are cast or wrought iron, notwithstanding the expense is far greater than what it would be in England. From this fact it is reasonable to assume that architects still love to cling to old traditions in lieu of entering on a new field. If by any mode of reasoning they could be induced to adopt the American system, the impulse it would give to the workers in iron cannot be estimated, and this without injuring existing trades. Whatever may be advanced to the contrary, as matters of fact the introduction of railways increased the value of horses, the introduction of iron shipbuilding, the wages of shipwrights, and the more universal adoption of iron in the building of houses would, in all probability, ultimately increase the earnings of joiners and house carpenters, by introducing improvements of style which need not be dwelt on here. However, the inexorable laws of supply and demand will assuredly force iron into more general use, for year by year the supply of convertible timber is growing less, and a forest which has been once felled is seldom replaced. If it were, at least two generations must elapse before it reached

maturity. From this serious drawback iron is wholly exempt, requiring but the skill of the miner and the smelter to raise it in unlimited quantities. In no other country up to the present time has the precious metal been found in such workable sites, or so near to the fuel which is required for extracting it. Vast as the mines may be which are opened up in the United States, their locality is generally remote from the great arteries and centers of commerce, thus rendering the cost of transport a serious item before reaching the market. Under anything like equal circumstances, this will long be a drawback on the energetic race across the Atlantic; so much so, that however they may strive to rival England in foreign markets, nothing short of misunderstanding and strikes in this country can give them a chance of success. Unfortunately, they have been of such constant occurrence during recent years as to damp the spirits of those enterprising men to whom the world is so deeply indebted. It is not going beyond the limits of probability to state that if the time which has been lost during strikes in the shipbuilding trades alone could be regained, the labor would complete a coasting fleet of iron steamers which might not only have tended to equalize the price of heavy goods throughout the United Kingdom, and to increase our foreign trade by enabling coals to be carried more cheaply to the Continent, but what is of more importance still, would also tend greatly to reduce the death roll of the maritime population. Unfortunately, a lamentable ignorance of the principles of political economy on the part of the leaders of trades' unions has prevented this, and the seeds of distrust between employer and workmen have been so industriously sown, that the two classes stand like rivals, possessing no common interests.

Commerce has been likened to a hardy plant which thrives best when untrammelled with artificial help. When the great political economist penned the lines, strikes and lock-outs were unknown; and when contracts were entered into there was a chance of carrying them to a successful issue on the basis of the original calculation. All this has been changed; and it is not long since the iron workers of all denominations on the Clyde remained out six months on strike, in the vain effort to force wages beyond the limits, which would not only debar the masters from receiving renumeration for the science and capital employed, but likewise involve them in heavy pecuniary loss. A few years since, £20 per ton could be demanded for the construction of a first-class iron ship, which now may be had for £12. Yet, under the leadership of designing or misguided men, the workmen essayed to dictate unbearable terms to their masters. They failed, as wrong always must, in the end; and the loss which has arisen to all concerned cannot be reckoned by the amount of wages and unemployed capital, but by the distrust it has engendered at home, and the encouragement it has given to rivals abroad. America, hoping that a recurrence of such catastrophes will ultimately drive a large portion of iron shipbuilding to her shores, has already relaxed in its favor the terms of that almost prohibitive tariff on iron and steel, and in future all materials used in the construction of ships are to be admitted free of duty. This is undoubtedly the first step towards a rivalry, which at no distant period may become formidable, especially if great lines of native steamships are ultimately established between the West Coast of America and China and Japan. English-built vessels now monopolize the lion's share of this lucrative traffic; but Americans are not slow to copy what is really useful.

Mr. Brassey touched on dangerous ground when, at a recent lecture, he announced that the peculiarly-trained touch of the English artizan made him superior to any in the world. There are grave reasons for believing that, when circumstances call it forth, the hands of our Transatlantic brethren will in nowise be less cunning than those of our own. Up to recent times they have had no inducements to finish their work in a style similar to that of this country; yet in many species of tools and agricultural machinery they already take the lead. Even the thoughtful and highly-educated German acknowledges this superiority, and is calling on his Government to more heavily weight the imports of the ingenious and self-reliant inhabitant of the New World. It is one of the triumphs of the engineer that his genius

has enabled this almost impossible innovation to be accomplished—an innovation which the most far-seeing men of the last generation could not have anticipated.

Shipbuilders appear to use iron more extensively than the members of any other profession. In none has it been of such vital importance to the welfare of the country, and its introduction was most opportune. The woods best adapted for the purpose of the naval architect had become scarce not only in England and the Continent, but in foreign countries. The African and Indian forests had been felled in almost every accessible locality on the banks of the great rivers and estuaries, and that which still remained inland failed to be of service for the lack of transport. Statesmen were talking of interdicting the felling of oaks, except for the construction of ships of war, when the substitution of an inexhaustible material set the question at rest for ever; and the grand old trees, no inapt representatives of the race who dwell around them, have been spared to adorn the landscape around English homes.

A movement has recently been inaugurated for the introduction of steel in lieu of iron for shipbuilding purposes. Of course, if successful, it will form a new starting-point in the art of enabling the merchant to have a vessel twenty or thirty tons per cent. under the present weight—no mean advantage in trades where the carriage of dead weight forms the most remunerative portion of his business. The innovation will have to be conducted with more than ordinary skill and care, from the fact that a rent, which might be of no practical importance in a bridge or a viaduct, might be fatal to a ship. The latter is subjected to strains which test the peculiar qualities of the materials forming the hull in a very marked degree; so much, indeed, that an unusually large factor of safety is adopted by all the great corporations when laying down their rules. Experience and careful study have barely mastered the laws which are necessary to be observed for the safe construction of iron vessels, when new have to be adapted in order that a higher classed metal may be introduced to supply its place. Great fficulties are certain to be met with at the outset. One of these—corrosion—appears to be almost insurmountable, and likely to deter shipowners and shipbuilders from bringing it into extensive use. There are others which, in a practical point of view, will always cause anxiety, such as docking, or lying in the tideway of a rapid river, notably the Mersey, or the Thames, during strong spring floods and gales. The rough knuckles of granite quays on a lee shore require a ship, when docking, to possess other qualities than elasticity and tensile strength, if her sides are to be preserved from bulging, or even fracture. In a similar manner the iron-plated sterns of the Runcorn flats, with their heavy lading of coals, or salt, or iron, would become dangerous to materials lighter than those now in use. Therefore, in making reductions, the laws of stiffness will have to be considered as well as the laws of strength, not only in what has now been mentioned, but in another respect still more important, which the reader will no doubt readily comprehend. The ship being a huge girder, with a top and bottom flange, and a connecting web in the form of topsiders, it is of the utmost importance for the true working of the machinery that all possible rigidity should be given to it. This cannot be secured without a certain thickness of the material employed, for, however great the tensile strength may be, it is only one of the indispensable factors demanded. The stems of the magnificent steamships of the White Star Line, during heavy weather, appear to rise and fall through an arc of eight inches, as measured by an imaginary line, on the break of the forecastle, by an observer close forward. A stronger but more ductile material would probably increase this to a dangerous extent. It is, therefore, evident that great caution and careful experiments will be required before steel can be largely introduced in the plating of the larger class of steamships employed in heavy carrying, and, it may be added, heavy driving trades.

The breadth of lap in their steel plates might probably be increased with advantage in double riveting for stiffening purposes, but not in single, for the caulking of the seam would present greater difficulties in the latter than it now does. It would not be desirable for this reason

to have a greater distance between the edge of the plate and the periphery of the rivet than what is universally allowed by scientific and practical men to be the best for all purposes.

There is still a doubt as to the efficiency of steel rivets, and Her Majesty's ships *Mercury* and *Iris* have been wholly fastened with iron. Under these conditions, the butts being the weakest part of the structure, extra precaution should be taken to make them approximate to the strength of the plates they connect, by an additional row of rivets wherever the strain is great. This plan has in all likelihood been adopted, otherwise the stronger material will more severely test the goodness of the joints than ordinary iron plates would do. For three-fifths of the length amidships, or in broadside ships the whole length of the battery, the butt straps should be treble riveted from the sheer strake to the neutral axis. The general custom now is only to double rivet, with the exception of the sheer strake. Messrs. Harland and Wolff have, in the construction of their ocean steamers, gone far beyond the requirements of any existing regulations on this important point.

In the construction of men-of-war, expense is not so much an object as efficiency, and no difficulties are likely to crop up on questions of finance. But in merchant ships, where economy is one of the primary laws governing the owner and the builder, the cost of an extra row of rivets in a large number of butts becomes of grave importance in times of high priced labor. Subjects of this nature must be left to regulate themselves. It is the profession of the engineer to ascertain what is practicable, and when that is accomplished to leave the monetary details in other hands. His specialty is to make much out of little. Good housekeeping is easy with unlimited means.

The mail steamers on the Atlantic cannot, without serious risk, reduce the thickness of the plates near the water-line owing to the danger of penetration by ice, which, in spring, may not only be found in the neighborhood of the Grand Banks, but in all the great commercial estuaries from the Chesapeake to the shores of Newfoundland. Anderson, in his highly useful manual, says there are no reasons for believing that iron is more brittle in winter than in summer, but qualifies the statement by adding that his experiments were made under cover. It is certain that seamen will not share his opinion, for they have a great dread of the action of intense frost on the plating at the water-line when steaming through an ice-field, especially if it be in hummocks, or greatly denuded by the weather. In this condition, it assumes a lustrous greenish hue, not unlike the tint of the glass which still may occasionally be seen in the cottages of rural districts. At this stage, granite scarcely surpasses it in hardness, and numerous accidents bear out the accuracy of the seaman's reasoning. In the winter of 1874–5, a large percentage of steamers in the North American trades met with serious damage to their bows or propellers, and one, the *Vicksburg*, burst the plates under the counter, and foundered in the vain attempt to back out of the pack. Of course, the theory nursed by seamen may be erroneous, but they are so thoroughly imbued with its correctness, that only practical tests will convince them that their assumption is founded on prejudice. The advocates for steel rivets assert that the defect which exists from burning may be obviated by more care in heating. Whatever may be done within the walls of a foundry, no precautions which can be used in a shipyard will prevent it. Rivet boys cannot be expected to study the temperature when they and the riveters are employed on piecework. Therefore, until steel can be tempered to stand without injury the same rough treatment as iron, there is not much hope of its being generally adopted in the construction of ordinary vessels, except for deck-ties, stringers, and bulkheads. It is unfortunate that the stiffness as well as the tensile strength of all parts which form a ship are tried in turn. If she grounds on a stony place, irregular bumps severely punish the spaces between the frames, and in some instances, puncture them badly. In a heavy seaway, the decks, sheer strakes, stringers, and bottom, are alternately exposed to tensile and compressive strains, and in docking or loading on a rapid river, the side plating is often tested to the utmost limits of endurance. Take, for an example, a case

of a long steamer entering one of the northern basins on the Liverpool side of the Mersey, which, during north-west gales, have no shelter from the Cheshire shore. But for that peculiar action of the waves known to seamen as the undertow or backwash, it would, at times, be impossible to drop alongside of such formidable walls. Occasionally, a sea rolls over the summit, as it might do in the open, and sends showers of spray to a considerable distance. The danger is in places increased by the want of a bold sweep at the corners, and also by the walls being built perpendicularly in lieu of with a slight curve. No amount of ordinary wear and tear strains and punishes a ship so much as the treatment they sometimes receive from these causes, which certainly might have been avoided when the works were planned. Injuries are often visible in the form of bulged plates, broken rivets, and cracked frames, and when the position of the ship is considered it is not to be marvelled at; she is converted into a huge lever, with the bluff of the bow for a fulcrum, and all abaft it for the long arm, to which may be attached one or more tugs backed by a powerful steam winch to break her round.

Three years since, the writer was requested to examine and report on the construction of a new wharf on the Hudson river, which was intended for the use of the steamers of one of the great mail companies. Through an oversight similar to that pointed out, the corners were badly rounded, and to make this defect more serious, they were lined with deep angle plates from the platform to mean low water level. The probable danger was pointed out to the gentleman who had designed the structure, and a sketch sent to Liverpool to illustrate it. No steps were taken to remedy the evil, one party alleging that it was not their business, and the other that the error, if it was one, should have been pointed out at an earlier date. The result was, that the second steamer which essayed to enter when the freshets were running down, stove in one of her bows, thus causing delay and expense. After the mischief was wrought, the corners were supplemented with circular turret-shaped projections, designed by the writer, and since their erection not the slightest injury has been sustained by any vessel. The American engineer was so much pleased with the simplicity and efficacy of the plan, that he has since announced his intention of adapting it in all docks or jetties, but in lieu of attaching them like patchwork, they will, for the future, form a portion of the permanent piling.

There are good reasons for believing that until experiments have convinced the shipbuilder of the degree to which he may test steel, it will only be largely used in the construction of men-of-war of certain classes, and packets for Channel service. In both, expense is not so much an object as lightness and efficiency, and neither are much subjected to the rude tests of strength which so frequently try the ordinary merchantman. Further, the cargoes of mail packets are seldom heavy, neither is space such an object as to prevent all the important parts of the hull from being made accessible for scaling and painting. Experience demonstrates that when this is carefully carried out, there is practically no limits to the duration of the plate. Whether Nature really holds in her laboratory an antidote to oxidization is uncertain, but we do know that up to the present time the highest chemical science has failed to find one. The greatest scientists have not been rewarded with a glimmer of success, although pretenders of all denominations essay to make the world believe they have solved the great problem. In despair, at the failure of numerous patents, one of the largest steamship companies in Liverpool has recently given orders that common lead paint is now only to be used. In the North Atlantic trade, where ships do not remain long in port, this may stand well, but in tropical seas or foul waters it does not meet the case. A few days of calm weather under the equator, enables animal and vegetable productions to attach themselves to a ship's bottom with marvelous profusion, and when this has commenced there are no means of checking the advance of both.

It will be interesting to note if iron and steel work harmoniously together; under what conditions, if any, wasting will occur to either, and whether the superior tensile strength of one will be in anywise detrimental to the other. It is scarcely possible that the former

occurs, but so many singular combinations take place in Nature, that it will be well to adopt every precaution. The latter is worthy of consideration, from the simple fact that the melting points of iron and steel being different, expansion may cause irregularities in practice which may not readily harmonize. In certain anchorages, chain cables after being submerged a few weeks are deeply scored, so much indeed, that the fiber of the iron stands clearly out, and in places cells resembling the half-section of those of the *teredo navalis* in timber may be traced. Few who have not examined a specimen of the links on the spot, would credit that so much mischief may be done to one of the hardest of materials by some unknown cause. When heaving in, the rust may be taken off like paste. It easily washes away, leaves no trace of weed or shell behind, which almost infers that galvanic action is the cause. Sailors attribute it to an insect, but whatever it may be, the injury arising from the submergence of a few weeks exceeds the ordinary wear and tear of years.

The above statement may be deemed irrelevant to the question. It is simply introduced to show that unexpected causes sometimes throw serious obstacles in the way of great innovations.

THE DRAINAGE SYSTEM OF GLASGOW.

From "The Engineer."

The irrefutable logic of hard facts and dearly-bought experience has completely dispelled the illusion which some time ago prevailed to a very considerable extent, that not merely profits but large fortunes were to be realized by the utilization of sewage. It is now thoroughly well known and acknowledged also, even by those who are somewhat reluctant to make the admission, that raw sewage cannot by any existing process or chemical treatment be converted into an artificial manure which will pay the cost of its own manufacture. A large class persistently refused to give the slightest credence to this view of the question, although it was supported and based upon scientific reports, chemical analyses, and the impartial statements of Royal Commissions, which must have carried full conviction to the mind of any unprejudiced person. It was indeed nothing but the actual loss of the money invested in one or more of the numerous precipitating schemes which finally and conclusively demonstrated to the shareholders the futility of their projects, and the fallacy of their expectations. It has been estimated that one well-known company beguiled the public of a million of money in their fruitless endeavor to effect the desired remunerative conversion. As we proceed with our subject it will be seen that the people of Glasgow are not likely to fall into this error, formerly so prevalent. They appear to be well aware of the specious and illusory nature of the processes, and while recognizing the suitability of the means employed for accomplishing the purification of the effluent water, they entirely discard the idea of attaching any value as a manure to the precipitated sludge. We are inclined to consider that their views in this respect are in the main pretty correct. Towards the close of last year a number of gentlemen were appointed by the Town Council of Glasgow to visit certain large cities and localities in England, to examine into the various systems in operation for the disposal of sewage and refuse matter, and to report upon them accordingly. Manchester, Leeds, Birmingham, our own metropolis, Bradford, Coventry, Croydon, Halifax, and Oldham were all utilized in this way.

The physical situation of Glasgow is similar to that of London, inasmuch as they both possess the great advantage derived from the contiguity of a large tidal river. This offers at once a ready and, in some measure, a natural outlet for the sewage of the riparian city, and so long as the volume of the sewage discharged into it remains comparatively

small, little or no harm is likely to result to the community. But no sooner do these conditions cease to obtain than the health of the inhabitants begins to suffer and the rate of mortality to increase. In order that a river should be maintained in a state of purity it is necessary that some authority should be appointed to take care of it. It certainly does not absolutely follow that the constitution of such an authority will ensure the river being maintained in a pure and unpolluted condition. There is an excellent body called the Thames Conservancy, but if we are to believe the statements of Captain Calver respecting the results of the metropolitan sewage system, the state of the Thames is not such as to reflect much credit upon its Conservators. Notwithstanding this, we entirely concur with the members of the Glasgow deputation, that until a Board of Conservancy is established for the Clyde, as recommended in the report of Sir John Hawkshaw, no works for the discharge of sewage into that river can be undertaken with hope of ultimate success. Contaminated as the Thames unquestionably is by the enormous and continual discharge of sewage into it, it is purity itself in comparison with streams such as the Irwell and the Bradford Beck. It is impossible to expect that rivers and streams similar to those alluded to, which have been permitted to become nothing better than common sewers of the foulest description, can ever be restored to a state of purity until a Conservancy Board is established with powers to deal summarily with all the polluting parties. The jurisdiction of such a Board, moreover, should not be confined to that portion of a river flowing through any particular town or district, but should embrace the whole drainage area of the basin belonging to it. It is the common, and, at the same time, very just complaint of the inhabitants of many of our large inland towns which are situated on the banks of small rivers, that it is not only a great hardship and expense, but a useless one as well, to compel them to purify their sewage before it is allowed to be discharged into streams which are already rendered as foul as they can possibly be by the filth of other towns.

Although the population of Glasgow is, in round numbers, about one-seventh that of London, yet the sewage of the former town ought not to be permitted to flow into the Clyde without previously undergoing purification. The average range of the tide at Glasgow harbor is only about half that of the Thames at the London Docks, and the average velocity barely exceeds a tenth. Purification of the sewage, either by irrigation or precipitation, before discharging it into the Clyde, is evidently more necessary at Glasgow, where a small range of tide and a feeble current prevail, than at London, notwithstanding the great difference in the relative population. If the sewage is to be purified by irrigation, land must be obtained for the purpose. In other words, an irrigation farm must be established. With regard to this method of dealing with this great sanitary question, the deputation came to the conclusion that "irrigation presents the most perfect means for the disposal and purification of sewage." It was also their opinion, founded upon the actual facts placed before their notice, that under certain favorable circumstances "a sewage farm might be made to yield a profit." The conditions are—the acquisition of land at a reasonable distance from any resident population; the purchase or rental of it at a fair agricultural value; and the distribution of the sewage by the principle of gravitation. The first of these conditions is no doubt advisable, but not absolutely necessary. In spite of several statements respecting the alleged danger to the public health by the establishment of sewage farms, we believe that no reliable evidence has been produced to show that any evil effects have resulted from the existence of such farms, or that the rate of mortality has risen in any town or village in proximity to them. As to the accuracy of their conclusions that a profit might be made, we might say that, up to the present moment, experience tends all the other way.

Of the many ingredients employed for precipitating the solid constituents of sewage, lime appears, in point of general application, to possess advantages over the others. It is cheap, can be readily procured nearly everywhere, and accomplishes the purification of the effluent sufficiently to enable it to be discharged

into any river, the water of which is not used for potable or culinary purposes. The objections against its employment are that its purifying effect is evanescent, and that it produces rather more sludge than some other systems. The first of these objections is merely one of degree; and with regard to the second, it may be observed that when adequate means have to be provided for the removal and disposal of some hundreds of thousands of tons of sludge, a few thousand more or less are not of much consequence, in comparison with the other merits of this particular process. One very ready and convenient plan for disposing of the sludge precipitated from raw sewage is to simply "run it to spoil," that is, to apply it to the making up of, or raising the level of waste and low-lying lands. To such an extent has this system of disposing of the solid contents of privies been for many years carried on in Manchester, that having reference to the large number of houses erected on land made up in this manner, it has been said, "Manchester is a town built upon dunghills." The idea is not by any means a pleasant one, although time and the sanitary influence of natural causes may have removed all noxious and deleterious qualities from the once polluted foundations.

The rate of mortality of any town may be fairly considered as the real test of the efficacy of its sanitary arrangements. An examination of this rate in many of our large towns reveals the very significant fact that the greater the number of water-closets—or, in other words, the greater the use of the water-carriage system—the healthier is the town. London, which is beyond all other cities that in which this method of removing the sewage from habitations is most extensively practiced, returns a rate, calculated on an average of five years, of 22.9. That of Coventry, in which town the number of water-closets is six times that of the privies, is 23.4. It is rather remarkable—although from various circumstances the case is somewhat exceptional—that the rate of mortality is only 19 in Croydon, a place where the water-carriage system is in full operation, and where irrigation is the method employed for utilizing the sewage. In Birmingham, where the rate is 25.2, the water-closets are in the minority; and in Manchester, where the number is comparatively very small, the rate rises to 30.0, and to 29.3 in Salford. Density of population cannot be urged as an independent cause of a high rate of mortality, because in the last two instances quoted, in which the rate is practically identical, the relative densities are as three to one. A comparison between Halifax and the metropolis will also serve to show that there is no necessary connection between these two particulars. The former town has a density of population of only 18 to the acre, with an average death rate of 26.6. The corresponding figures for London are 45.7 and 22.9.

The report of the "deputation" contains some final recommendations with regard to the sanitary measures to be carried out in Glasgow. The majority of these are well known to every engineer and local surveyor, although not always put into execution by the corporations under whom they act. It is recommended that "water-closets in small houses should be discouraged." This would appear to intimate that there should be in Glasgow one system of sewerage for the rich and another for the poor, yet, in a sanitary point of view, there should be no such distinction. Otherwise there is the risk of the water-carriage plan being considered in the light of a luxury to be enjoyed only by the wealthy. Some years ago this, no doubt, was the case. Another of the "recommendations" is to the effect "that the ordinary privies and ashpits be altered to the tub and pail system, to be cleansed daily, as it has been carried out in Manchester." It is a little singular that the deputation should recommend for adoption a plan which, it is said, has earned for the city in question the highest death-rate of all those we have mentioned. The rate of mortality in Glasgow itself is 29.9, so that it can hardly afford to bear any increase.

For the purpose of hardening wood pulleys, the pulley, after it is turned and rubbed smooth, is boiled for about eight minutes in olive oil. It is then allowed to dry, when it will become exceedingly hard.

APPARATUS TO MEASURE DIRECTLY THE STRAIN TO WHICH THE PIECES OF AN IRON LATTICE GIRDER ARE EXPOSED.

By Prof. WILLIAM WATSON, Ph. D., late U. S. Commissioner.

DESCRIPTION; APPLICATION TO A SET OF BARS; EXPERIMENTS ON A LATTICE GIRDER; RESULTS.

In order to ascertain as accurately as possible the amount of the tension, or compression, produced in each of the different iron bars which make up a lattice-girder, the Orleans Railway Company caused numerous experiments to be made upon such a girder, 12 meters long and 1.12 meters high; and the results show that in future a notable economy may be obtained in such girders by a different arrangement of the metal.

DESCRIPTION OF THE APPARATUS.

In order to perceive directly the effect produced upon each bar, to judge of its nature, and to measure exactly its intensity, whether it be extension or compression, M. Dupuy, Chief Engineer, devised the following apparatus; it consists (Fig. 2) of an iron bar pierced at its two extremities, with two holes, A and B, exactly 1 meter apart; this bar is joined at one end with a second bar pierced with three holes, C, D, E, the distances CD and DE being 5 and 100 centimeters respectively, thus forming a bent lever. Two holes, exactly 1 meter apart, are drilled in each bar to be tested, the bent lever is attached to it by the points A and D and the test-load applied. Then as the bar AD lengthens or shortens, the two rods of the bent lever turn around the center C, and as CD is one-twentieth of DE, it follows that the extremity E passes over a space equal to twenty times the amount of expansion or contraction of the bar. A graduated scale serves to measure the space through which the extremity E moves.

The apparatus was first tried by measuring the extension of several iron bars firmly fixed at their upper extremities and supporting a scale-pan, upon which weights were placed. In order to avoid drilling the bars, saddles were screwed very tightly upon them, one of which supported one extremity of the bent lever, and the other the pivot of the index-hand. Also a second system of bent levers, exactly like the first, was placed behind the bar to correct the small errors resulting from torsion.

Three bars were tested, of which the dimensions of the sections were (Plate I) 200 millimeters by 93 millimeters, 270 millimeters by 52 millimeters, and 157 millimeters by 36 millimeters, and the proportional elongations were 0.09 millimeter, 0.18 millimeter, 0.28 millimeter, 0.37 millimeter, under a load of 2, 4, 6, 8 kilograms, respectively. These results agree with those generally adopted, viz., 0.50 millimeter under a load of 10 kilograms per square millimeter of section.

The girder specially constructed for the tests was formed of two flanges united by lattice-bars at 45°. Each flange was formed of two plates, at right angles, held together by two angle-irons. (See Figs. 1 to 5, Plate II). Dimensions of the lattice-bars: First set, 140 millimeters by 9 millimeters; the second set are flanged and are 75 millimeters by 75 millimeters by 10 millimeters.

The top and bottom horizontal plates are 220 millimeters by 20 millimeters; the vertical plates 250 millimeters by 20 millimeters, and the angle-irons 100 millimeters by 100 millimeters by 12 millimeters. Each of these lattice-bars had the measuring-apparatus described above.

The upper and lower flanges of the girder were connected to the walls by jointed iron rods to prevent these flanges from warping, and the testing apparatus was applied at five equi-distant points of the upper, and at five of the lower flange, The girder was then successively subjected to the action of uniformly distributed loads as follows: viz., 5,000, 10,000, 20,000, 30,000, 35,000 and 40,000 kilograms. The results of the last tests, viz.: the observed and the computed stresses upon the diagonals and upon the upper and lower flanges, resulting from a uniformly distributed load of 40,000 kilogrammes are given in Tables I and II.

Plate I.

Fig. 1.—General elevation.

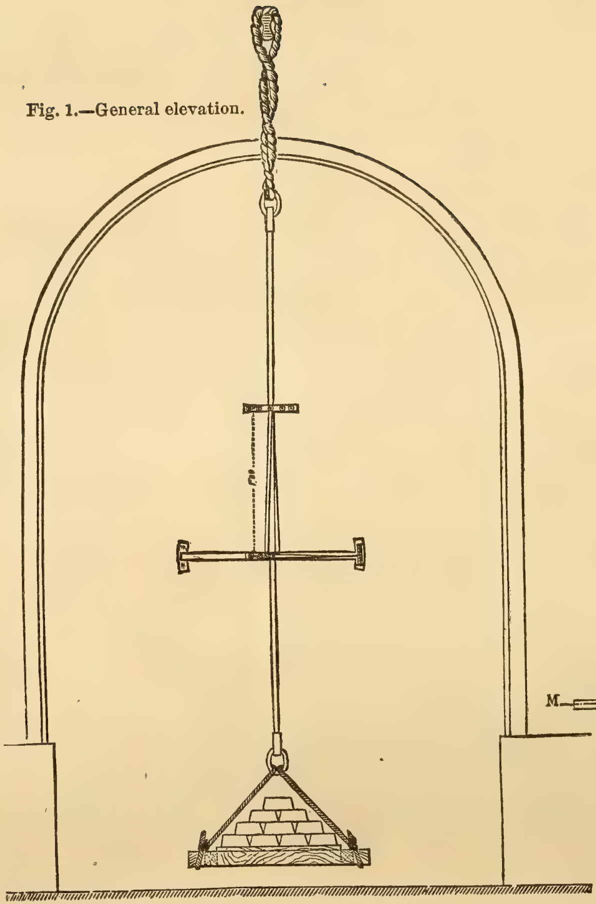


Fig. 2.

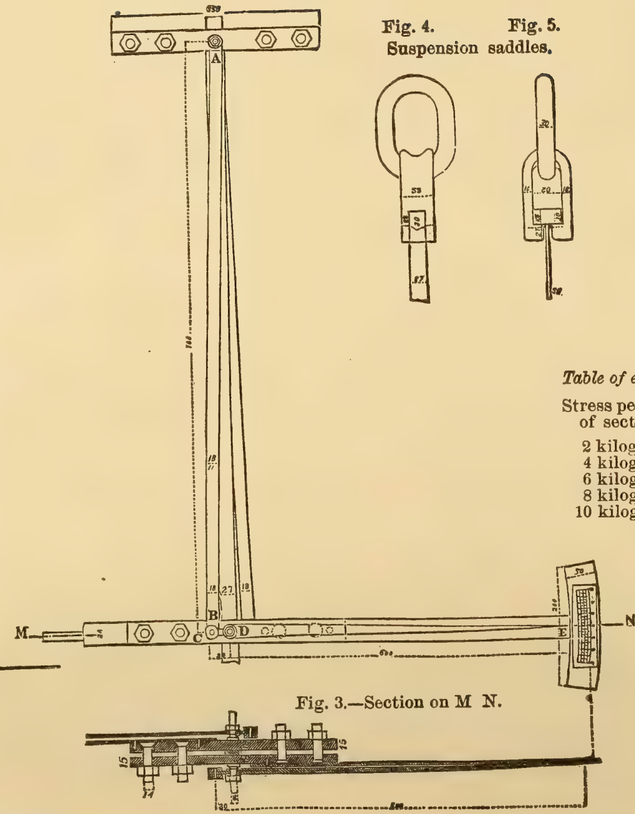


Fig. 3.—Section on M N.

Fig. 4. Fig. 5.
Suspension saddles.

Section of bars tested.
Fig. 6.

Fig. 7.

Fig. 8.

Table of elongation per meter.

Stress per mm. of section.	Elongation.
2 kilog.	0. 087 mm.
4 kilog.	0. 183 mm.
6 kilog.	0. 286 mm.
8 kilog.	0. 376 mm.
10 kilog.	0. 476 mm.

Scales.
Fig. 1 = $\frac{1}{40}$
Figs. 2–8 = $\frac{1}{10}$

APPARATUS TO MEASURE ELONGATIONS OF IRON BARS IN TENSION.

PLATE II.

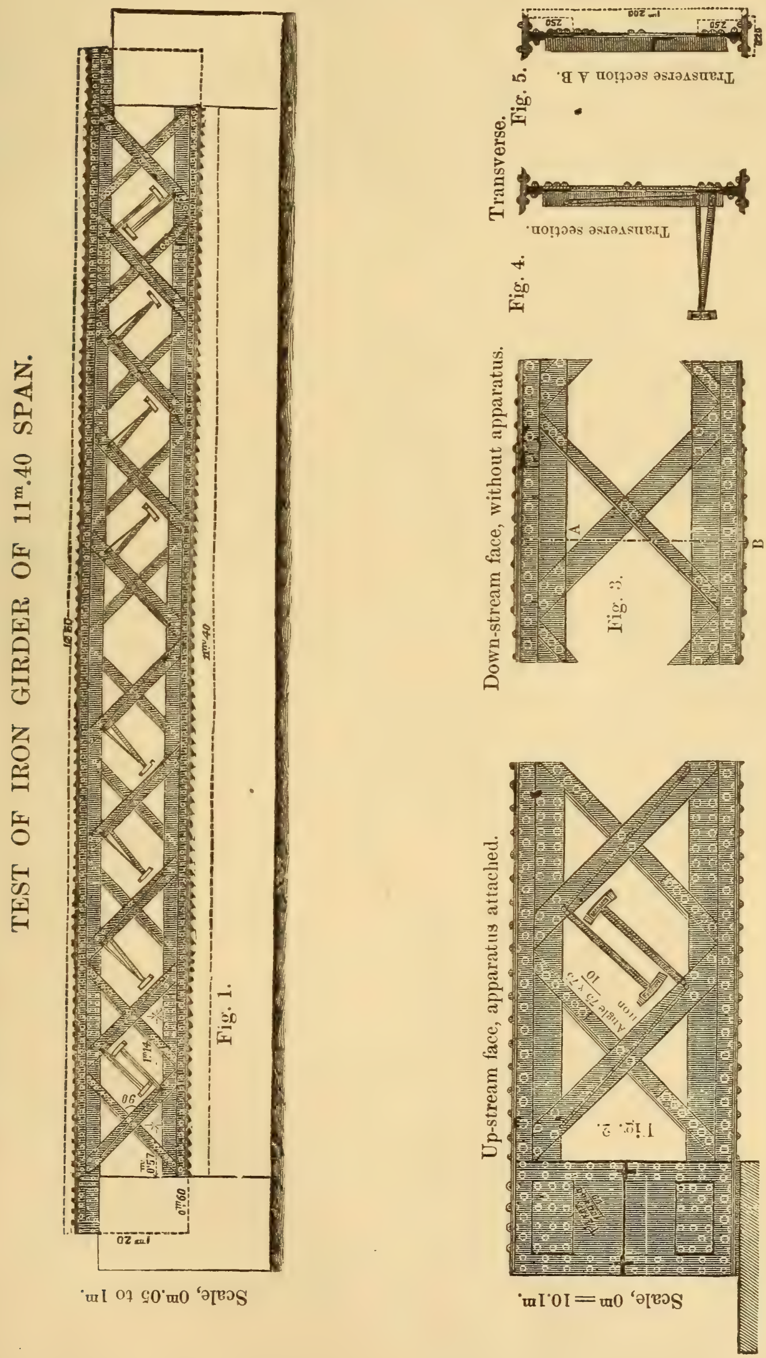

TEST OF IRON GIRDER OF 11m.40 SPAN.
Fig. 1.
Scale, 0m.05 to 1m.
Up-stream face, apparatus attached.
Fig. 2.
Angle 75 x 75/10 iron
Scale, 0m = 10.1m.
Down-stream face, without apparatus.
Fig. 3.
Fig. 4.
Transverse section.
Transverse.
Fig. 5.
Transverse section A B.

Table III shows the observed and computed stresses on the diagonals for the case in which a load of 20,000 kilogrammes was concentrated in the middle.

RESULTS.

From tables it appears:

1st. That the stresses on pieces symmetrically placed with respect to the middle of the girder were nearly identical.

2d. That for the uniformly distributed load the flanged diagonals were all compressed.

3d. That the plane diagonals were all extended except those near the middle.

4th. That the stresses on the diagonals diminished in passing from the abutments toward the center.

For the case in which the load of 20,000 kilogs. was concentrated in the middle it appeared that the stresses on the diagonals of the first pannel were about one-half those on the same diagonals for the case of a uniformly distributed load of 40,000 kilograms.

Table II shows the stresses at five equally distant points on each flange, and extending over a length equal to half that of the girder.

In this test the flanges had been weakened near the abutments, a piece of the horizontal plate $3^m.30$ long and $0^m.010$ thick having been cut away from each extremity, thus reducing each flange, for these portions, to the vertical plate, and two angle irons.

CONCLUSIONS.

The results obtained by these experiments showed that the effects produced upon the lattice-bars were scarcely one-half of those indicated by the common formulæ; and that toward the middle of the girder the bars inclined toward the points of support were extended, while the other set were compressed, which is contrary to the ordinarily received hypothesis. It was also certain that the *rigidity* of the joints of these girders, the parts of which are carefully riveted together, has a considerable influence upon the strength and flexibility of lattice-girders. It is very desirable to measure the real effects which are produced upon the great lattice-girders of bridges already constructed, and this apparatus is well adapted to this purpose.

TESTS OF THE GIRDER.

TABLE I.—LOAD 40000 KILOGS. UNIFORMLY DISTRIBUTED. (Stresses on the Diagonals.)

Nos.	Stresses on the Plane Diagonals.		Stresses on the Flanged Diagonals.	
	Observed	Calculated	Observed	Calculated
1	+ 5418	+ 14140	— 5180	— 14140
2	+ 2520	+ 11312	— 5320	— 11312
3	+ 1260	+ 8484	— 420	— 8484
4	+ 882	+ 5656	— 1120	— 5656
5	— 1890	+ 2828	0	— 2828
6	0	+ 2828	— 1386	— 2828
7	— 1400	+ 5656	— 882	— 5656
8	+ 1820	+ 8484	— 1890	— 8484
9	+ 4340	+ 11312	— 3150	— 11312
10	+ 5600	+ 14140	— 5166	— 14140

TABLE II.—LOAD 40000 KILOGS. UNIFORMLY DISTRIBUTED. (Stresses on the Flanges.)

Nos.	* Stresses on the Upper Flange.		Stresses on the Lower Flange.	
	Observed	Calculated	Observed	Calculated
1	—13306	— 21162	+ 4435	+ 21162
2	—36115	— 34699	+29779	+ 37699
3	—34998	— 47375	+32437	+ 47375
4	—44387	— 54118	+37558	+ 54118
5	—51216	— 56338	+42680	+ 56338

TABLE III.—LOAD 20000 KILOGS. CONCENTRATED IN THE MIDDLE.

(Stresses on the Diagonals.)

Nos.	Stresses on the Plane Diagonals.		Stresses on the Flanged Diagonals.	
	Observed	Calculated	Observed	Calculated
1	+ 2394	+ 7070	— 2380	— 7070
2	+ 1512	+ 7070	— 1260	— 7070
3	+ 1386	+ 7070	+ 280	— 7070
4	+ 3654	+ 7070	+ 840	— 7070
5	— 2268	+ 7070	— 980	— 7070
6	— 420	— 7070	+ 2898	+ 7070
7	— 428	— 7070	+ 2520	+ 7070
8	0	— 7070	+ 2520	+ 7070
9	— 700	— 7070	+ 1260	+ 7070
10	— 2100	— 7070	+ 2142	+ 7070

* On five equally distant points extending along one-half the length of the girder.

[In a recent letter to the author, M. Dupuy, says: "This simple apparatus has recently been used to ascertain directly the resistance of the different parts of a bridge—le Pont de Roland, having a span 24.5 meters, consisting of two lattice-girders; the results were very remarkable and have verified the theory held by French engineers, by showing that the riveting of the lattice-bars has the effect of materially diminishing the work done by these pieces. The apparatus should be applied only in those cases in which the pieces to which it is fastened preserve their neutral axis unchanged by the load between the points of attachment and the apparatus."]

An account of the tests of this, and of other bridges by the above apparatus, the results obtained, and the modifications of the present theory of lattice girders which these results seem to require, must be reserved for a subsequent communication.

ON STEAM BOILER EXPLOSIONS, AND EXPERIMENTS IN RELATION THERETO.

By Dr. HERMANN SCHEFFLER.

From "Organ fur die Fortschritte des Eisenbahnwesens," Foreign Abstracts of the Institution of Civil Engineers.

The Author is disposed to refer many boiler explosions to the creation of a marked disproportion between the external pressure acting on the boiler water and its internal temperature. This may act in two ways: (1) as a primary cause of explosion where the taking off of the pressure produces a sudden and violent generation of steam, the shock of which is greater than the boiler can withstand; (2) as a secondary cause where a rent in the boiler produced by some other means creates the disproportion, and the ensuing generation of steam comes in to render the explosion much more violent and destructive. The second fact is generally admitted, but as to the former there are great differences of opinion, and it is therefore desirable that the point should be cleared up by actual observation on the fluctuations of pressure and temperature occurring within steam boilers under various circumstances.

With this view the writer affixed three thermometers (made specially for the purpose by Messrs. Schaeffer and Budenberg) to different parts of the boiler of a locomotive, viz., one in the front of the boiler, close to the entry of the feed-pipe, and, therefore, where the lowest temperature might be looked for; the second about the middle of the length of the fire tubes, where the temperature would probably be highest; and the third in the front of the fire-box and near its top. A large series of observations were taken of these thermometers by competent persons, and at short intervals. The results are embodied in a table, which gives for each observation, (1) the actual pressure at the moment as given by the pressure gauge, in atmospheres; (2) the readings of each of the three thermometers; (3) the theoretical pressure of steam corresponding to each of these temperatures, as calculated by the formula of Regnault. The observations fall into four groups according to the following condition: (A) engine standing, feed shut off; (B) engine standing, feed going on; (C) engine running, feed shut off; (D) engine running, feed going on. Separate observations were taken with three different descriptions of feed apparatus, viz., an injector, a plunger pump, and two plunger pumps combined. Separate series of observations were also taken when the pressure was rising, and again when it was falling.

The pressure as given by the gauge in every case differed from the theoretical pressure deduced from the temperatures. As these latter always varied among themselves, exact agreement was of course impossible; but this was not enough to account for the differences observed, which may possibly be attributed to defects of the gauge, but should

rather be taken into account among the general results of the experiments. These are as follows:

(1) When the feed was shut off, whether the engine was standing or running, the thermometers at the fire-box and in the middle of the boiler gave very nearly equal readings. At the smoke-box end the temperature was somewhat lower, but the difference was not above 5°.

(2) With the feed shut off, but with rising temperature and pressure, the indicated tension of steam in the steam space was about 0.2 atmosphere (3 lbs.), higher than the theoretical pressure at the hottest part of the water: with falling temperature and pressure it was about as much lower.

(3) When the feed was opened the temperatures at the three places fell unequally; the fall being least in the middle, greater at the fire-box, and greatest at the smoke-box near the entry of the feed-pipe.

(4) Where the feed was effected by an injector these differences were least, not exceeding 7°; with a single pump they amounted in some cases to 9½°, and with two pumps to as much as 17½°, corresponding to a difference of pressure of 2¼ atmospheres (about 35 lbs.).

(5) A fall in the temperature of the water was in all cases followed by a fall in the tension of the steam; but when the cooling was rapid this fall was less in proportion to it, so that the actual tension became higher than the theoretical pressure at the points of observation. The greatest difference so observed amounted to 2¾ atmospheres.

(6) While this held in general, there were cases where, at the commencement of the feed, the theoretical pressure at the hottest point was for a short period higher than the actual steam tension, the greatest difference, however, not exceeding 0.43 atmosphere.

(7) When the injector was used the temperature of the feed-water, immediately before entering the boiler, was from 40° to 60° higher than that of the tender-water. This, of course, accounts for the inequalities of pressure produced by an injector being much smaller than by a pump.

(8) A sudden opening or closing of the regulator produced an instant fall or rise of the pressure gauge of about 3 lbs., or 1½ lbs. respectively, followed in general by a slight recoil towards the original standpoint.

(9) The opening of the regulator caused a rapid fall of the thermometer which at that moment stood highest, and a rise of that which stood lowest, amounting in each case to about 3½°, thus producing an equalization of temperature to the amount of about 7°.

The following general conclusions are drawn from the above facts by the writer:

(1) The supply of water by feed-pump causes large variations of temperature in the different parts of a boiler. These act on the steam tension, but with the general result that this tension is decidedly in excess of the theoretical pressure due to the water temperature: thus fortunately tending to retard, and not to accelerate, the generation of steam.

(2) At the first moment of opening the feed the converse is observed, the steam tension being about 0.4 atmosphere in defect of the theoretical pressure. The same holds to a smaller extent when the feed is shut off, provided the temperature and pressure are falling at the time.

The explanation of the above facts is obvious. When the pressure is lessened by the steady abstraction of steam it falls steadily both in the water and the steam space. When the abstraction is rapid (as with steam blowing off) the water maintains for a time a higher temperature than the steam space, with a corresponding generation of steam. When the pressure is lessened by actual cooling of the water, the steam only follows it gradually, and keeps up for a time a higher tension. The slight converse effect, at the moment of opening the feed, is accounted for by the additional consumption of steam due to the feed-pump, and perhaps by a slight condensation of steam effected by the first entry of the cold water.

(3) When the temperature and pressure are rising instead of falling, the steam tension will similarly appear in excess or in defect of the theoretical pressure, according as the original cause of the rise is a checked consumption of steam or a more rapid generation. The first case is shown in the experiments

when the engine was standing, the second on several occasions when it was in motion.

(4) Wherever pressure is taken off water, which is above the boiling point, a sudden generation of steam must ensue. This has been actually observed in the experiments to take place to the amount of ½ atmosphere under ordinary conditions. In exceptional cases it might be much greater, especially when the large differences of pressure at different parts of the boiler (sometimes amounting to thirty lbs.) are taken into account. The sudden spring of the pressure gauge at the opening and shutting of the regulator indicates the violent effects which rapid changes of this kind would produce in a mass of vapor at high tension. The Author thus considers himself to have shown that under a rare but not impossible combination of unfavorable circumstances, a sudden generation of steam might occur violent enough to burst, if not a new boiler, at any rate one deteriorated by long working. At the same time the much slighter effects of this kind produced by an injector, as compared with a feed-pump, should be noted as forming a substantial advantage on the side of the former.

INFLUENCE OF THE MOON ON THE EARTH'S MAGNETISM.

By JOHN ALLAN BROUN.

From "Nature."

THERE is a fact in connection with the moon's influence on our earth for which an explanation is necessary, and M. Faye has proposed for this end a hypothesis in advance. He had already pointed out Dr. Lloyd's investigation which showed that the diurnal magnetic variations could not be explained by the hypothesis that the sun acts as a magnet. But, it is said, "May the moon not acquire induced magnetism under the action of the earth, perpetually variable according to the relative position of the two bodies? If we consider the enormous magnetic power of the earth, that Gauss finds equal to that of 464 trillions* of magnets weighing a pound each, and if we remark besides that the distance of the moon to the earth does not exceed thirty times the length of this gigantic magnet, we may give an affirmative answer to the question proposed. But then the magnetism induced in the moon should in its turn exercise a small action upon the proper magnetism of the earth in the period of a lunar month. The observations alone can decide this provided they are of great precision."

M. Faye then cites the results obtained from the Toronto observations by Gen. Sir E. Sabine, that for the magnetic declination showing a range of 0.64; and he adds, "All these effects are of double period; they show two maxima and two minima in the course of the lunar month of 29½ days, which proves that they are due to an induced or reflex action, not to a direct action of the moon herself." I shall put my remarks on this subject under three heads.

1. Is such a result possible for the moon's synodical revolution? Let us commence with full moon at the winter solstice; near this epoch the moon is in the plane perpendicular to the ecliptic passing through the earth's magnetic axis and the sun. The north pole of the terrestrial magnet is then presented to the moon in such a way as to produce the maximum of induction; when the moon is near her third quarter the two terrestrial magnetic poles will be equidistant from the moon and the inducing action will be a minimum; there will be a second maximum near new moon when the south pole is most presented to our satellite and a second minimum near the first quarter. If now we follow the earth in her revolution to the vernal equinox, we shall find all this changed. At full moon our satellite is then equidistant from the two terrestrial poles, and the inducing action is a minimum;

* M. Faye uses the word trillions, but the trillions are English, not French, the latter being a very different number.

it is a maximum, on the contrary, near the first and third quarters. The consequence will be that if any inducing action existed it would have the same value at all ages of the moon in the mean of observations made during a series of years, such as were employed by Sabine for the variations in question. Such a result, however, as has been imagined by M. Faye might be possible if, instead of the synodical, we employ the tropical revolution of the moon, which occupies nearly 27.3 days.

2. We may inquire, then, if the moon as a permanent or induced magnet can produce any magnetic variations appreciable by our instruments? In the first place, Mr. Stony has shown that if the moon were as magnetic, bulk for bulk, as our earth, her whole action in deflecting a freely-suspended needle in our latitudes could not exceed one-tenth of a second of arc ($0''.1$). In order to consider the question of the variable magnetism induced in the moon by our earth, let us suppose her inductive capacity equal to that of cast-iron. From Barlow's experiments at Woolwich with iron balls I find that the magnetism induced in an iron ball of one foot diameter is about 2.0, in English units, which is nearly twice the magnetic force given by Gauss for the same volume of our earth. Barlow found the induced moments of different balls to vary as their volumes, and assuming that the induced magnetism varies inversely as the cube of the distance of the inducing and induced bodies, we find at the moon's distance (60 terrestrial radii) the induced magnetism at the maximum, under the most favorable condition, could not be more than $\frac{2}{60^3}=\frac{1}{108,000}$ of that supposed in the first case, that is when as magnetic as the earth. Her whole action on a magnetic needle here, then, due to the earth's induction, could not exceed one millionth of a second of arc. It is advantageous to get rid of hypotheses which are so completely insufficient, and we may put aside for the future any consideration of the moon's action by her own permanent magnetism, or by a variable magnetism induced in her by the earth.

3. M. Faye has also misunderstood the facts which he wished to explain. The results obtained by Sabine have reference to a variation which occurs in $24\frac{3}{4}$ *hours*, the lunar *day*, and not the lunar month of $29\frac{1}{2}$ days. The laws of the lunar diurnal variations were obtained first by Kreil for the magnetic declination, and by myself for the magnetic force and inclination. This action of the moon is, however, so very different from what is generally supposed, and from what was concluded from the first investigation on the subject, that it is of the greatest importance, in relation to the whole question of cosmic meteorology, I should state some of the more marked facts which have been deduced from eleven years' hourly observations on the magnetic equator. I shall limit myself at present to the lunar actions on the *direction* of the horizontal magnetic needle.

The moon, in a lunar day of 24.7 hours, produces a variation in the earth's magnetism, such that the magnetic needle makes *two* complete and nearly equal oscillations from an easterly to a westerly position in the interval in question. This is the general *mean* law. We have seen, in considering the law of the solar diurnal variations that, near the magnetic equator, the law becomes reversed when the sun passes from the one hemisphere to the other, so that when the sun is north, the movement of the needle is like that in high north latitudes, and when south, like that in high south latitudes. If, then, the moon acts in the same way as the sun, we should expect a similar phenomenon for the lunar diurnal variation when the moon crosses the equator. This is not the fact. The law differs little for the position of the moon north and south of the equator.

There *is*, however, an inversion of the lunar diurnal oscillations; thus, in the months of December and January the north end of a magnetic needle is farthest *east* when the moon is on the upper and lower meridians, and farthest west near moon-rise and moon-set; whereas in the months of June and July the reverse is the case, the north end of the needle being farthest *west* when the moon is on the meridian (upper and lower) and farthest east when she is on the horizon. It followed from this, as for the solar diurnal law, that the

oscillations should be in opposite directions at the same time in the higher latitudes of the two hemispheres, as has been found to be the case.

It is not then when the moon crosses the equator but near the times when the *sun* does so, that the moon's action is reversed.

The dependence of the lunar action on the position of the sun becomes more evident as the investigation becomes more detailed. When we determine the mean law for each month of the year, we find that the north end of the needle moves equally far east and equally far west at each of the two oscillations in the lunar day; this is not found to be the case for different positions of the moon relatively to the sun. Thus in the quarter lunations including full moon, in the months of December and January, the greatest *west-east-west* oscillation of the needle occurs when the moon is on the *lower* meridian; not when the moon, but when the *sun*, is shining on the place of the needle. The oscillation from moon-rise to moon-set, that is to say, while the moon is above the horizon, is little more than one-third of the oscillation for the half day when she is below the horizon; the two westerly extreme positions when the moon is on the horizon are nearly the same.

Similar results are obtained for the other quarter lunations. In all cases that oscillation is the greatest of the two for which the sun is above the horizon, whether the moon be above it or not.

There are still some remarkable facts connected with this variation at the magnetic equator. Limiting our examination of them always to December and January, we find, if we determine the oscillations due to the moon for the day when she is in conjunction and for each of the six following days, that in the first three days of the seven the oscillation is *west-east-west* during *the day*, that is, from sunrise to sunset; and in the last three days it is *east-west-east*. In the middle day of the seven the lunar action is almost null; the oscillation of the needle is very small, as we might expect, since on that day the change at sunrise from a *west-east* to an *east-west* motion takes place. The lunar hours of the maximum and minimum extremes thus oscillate about two hours on each side of the mean, depending on the position of the moon at *sunrise*.

The action of the moon, then, is dependent on the sun's position relatively to the equator (or the earth's position in its orbit), and on the position of the moon relatively to sunrise and sunset. But there is no relation between the laws and amplitudes of the solar and lunar diurnal oscillations. In the months from which I have taken my illustrations, the solar diurnal variation is a single oscillation; that for the moon, however taken, for single days, for quarter or for whole lunations, is always double. Through the combination of all the varying modes in which this oscillation is produced from day to day, *the mean for a lunation* is a regular double oscillation. The amplitude of this mean oscillation is three times as great in January as in June or July; whereas the amplitude of the mean solar diurnal variation is a half greater in June or July than in January.

I shall add another fact, one of the greatest importance in connection with this subject. We have seen that the lunar diurnal variation changes in the relative *amplitudes* of the two oscillations from day to day; the consequence of this is that when the means for a whole lunation, or even a quarter lunation, are taken, the mean amplitude is much less than that which is shown by each day separately. Thus I have found that the range of the mean lunar diurnal oscillation for the lunation December 16, 1858, to January 15, 1859, at Trevandrum, was 1′.25, while the ranges of the mean oscillations for the quarter lunations varied from 1′.70 2′.70, these quarter lunations giving exactly the same laws as have been deduced from eleven years observations for the same lunar epochs.

In order to understand the value of these results we must compare them with the ranges of the solar diurnal oscillations for the same months; those for December, 1858, and January, 1859, were 2′.20 and 2′.24 respectively. And as on some days the lunar diurnal variation has amounted to nearly 5′.0 (which is equivalent to 12′ in England with the smaller directive force), it appears that the lunar action is sometimes greater than the solar action at the magnetic equator.

As long as the lunar diurnal action was considered to be of the minute character first discovered, it was always possible for the supporters of the heat thesis to suspect that some small unknown heat action was in question. Such an idea is no longer possible. The lunar is sometimes greater than the solar diurnal action; and the former is dependent for its magnitude on the light and heat vibrations *due to the sun* shining on the place of the magnetic needle.*

If the solar light and heat vibrations can increase the magnetic action, there can be no difficulty in believing that these vibrations may in their turn suffer some modification of intensity. It would be difficult to measure small variations of the sun's light with sufficient accuracy as yet, though Mr. Willoughby Smith has suggested a selenium photometer for this end; we can, however, measure the variations of temperature, and the fact that the direct heating action of the moon is inappreciable is no longer sufficient to disprove the results of Madler, Kreil, Park Harrison, and Balfour Stewart. We have in fact a mode of lunar action with which M. Faye was unacquainted and could not take into account. The whole basis of his argument is therefore destroyed.

The view now given opens up a wide field of inquiry, and cosmic meteorology appears under another aspect. I hope to be able at another time to present other facts which seem to relate to magnetical and meteorological phenomena.

* Mr. Willoughby Smith's experiments show that the light vibrations of the ether in selenium diminish in a very marked manner the electrical resistance of the crystal; and it does not seem improbable that the increase of the lunar magnetic oscillation in sunlight may be due to some similar action.

THE SEWAGE SYSTEM OF PARIS.

From "Engineering."

In anticipation of the intended visit to the sewage system of Paris, by the Institution of Mechanical Engineers, during the forthcoming visit of that body to Paris, we propose to bring together a few notes upon the subject, which may be found of interest.

The area enclosed within the fortifications of the city may be put down at 19,000 acres. The quantity of water distributed for miscellaneous service over this area per day is about 46,000,000 gallons, and the average daily rainfall is some 22,000,000 gallons. About twenty per cent. of this quantity is absorbed by evaporation, leaving 54,400,000 gallons to be dealt with. This water is loaded with the *debris* from the streets, and the impurities from manufactures, house refuse, stables, &c. The sewage properly so called does not enter the sewers, as it is dealt with separately. Roughly speaking there are about 100,000 water-closets in Paris, of which a small proportion is provided with separators that retain the solid excreta, while permitting the liquid portions to pass into the sewers; the remainder are chiefly emptied into cesspools. The present system is of very recent date, but partial drainage works for conveying the sewage into the Seine were constructed at a very early period. In 1831 the remains of sewers dating from the time of Philippe le Bel were found underneath the Palais de Justice; but the conduits then formed were only for the service of a few palaces or other important buildings. In early times the Cite discharged its sewage into the Seine, the University quarter on the left bank, into the Bievre, and the town, properly so called, into the Menilmontant brook. As for the neighboring slopes of Charonne, Menilmontant, Belleville, and Montmartre, the porous surface soil absorbed a large proportion of the sewage, which—partially filtered—found its way into the Seine. The brook of Menilmontant was through several centuries known as the main sewer of Paris, and many roughly constructed channels were made from time to time to converge into it. About 1550 under the reign of Henri II., a very important effort was made to improve the condition of the city. A scheme was prepared by an en-

gineer of the period—Gilles Desfroissis—to divert the water of the Seine into the sewers and channels, natural and artificial, and by means of sluices to create a constant current of water, which should carry away all obnoxious matter down to a suitable point of discharge. This project, however, was opposed by the city, and nothing came of it. In 1605, under Henri IV., Prevot Francois Miron arched over at his own cost the Ponceau sewer, which extended from the Rue St. Denis to the Porte St. Martin. In 1611, Hugues Cosnier, director-in-chief of the Loire Canal, revised the project of Desfroissis but failed; in 1631, engineer Pierre Pidou was charged with the work of enlarging the city by enclosing within the *enceinte* of the Tuileries, the Faubourg St. Honore as far as the Rue Royale, and the Faubourg Montmartre as far as the present boulevards. In the course of this work he made the sewers navigable from the Arsenal to the Porte de la Conference, and constructed near the walls of the city a large sewer twelve feet in width. At this time there were about 12,000 yards of sewers of all kinds in and around Paris, the greater portion in so bad a condition that many workmen employed in repairing them were killed. It may be worth noticing that the physicians of the period on inquiring into the cause of these deaths, so far from recognizing the real reason, reported that the men in question were killed by the stare of a basilisk which they asserted inhabited the sewers. In 1667 the service of police was created, and shortly after a municipal ordonnance enjoined an annual inspection of the sewers by the various prevots, who were to take steps for their maintenance. But in spite of this, matters went from bad to worse, the sewers became choked and absolutely useless, even to convey the sewage into the Seine, where it had so long been a grievance to the water-side population; and on the 24th of April, 1691, a decree was issued for the formation of a commission to study the whole subject and devise a remedy. In a map of Paris, dated 1592, the brook of Menilmontant as it then existed is shown. The banks were sloped and planted with trees, and its principal tributaries were the sewer from the Rue des Egouts, between Rue St. Martin and Rue St. Denis, the Montmartre sewer, and the Gaillon sewer, which afterwards was converted into the Rue de la Chaussee-d'Antin. The land in its vicinity was deserted, for no houses could be occupied near it. But it was not till about 1730 that extensive operations were undertaken to ameliorate the condition of the city. Michel-Etienne Turgot, father of the great minister, engaged seriously in the work; he constructed an open channel in stonework, and provided means for its easy cleansing, and he formed also a reservoir at the end of this canal to receive the contents of the Belleville sewers, which then flowed through the canal. A map, dated 1765, shows the extent of the works carried out by Turgot. The canal followed the Rue des Fosses-du-Temple, where for part of its length it was arched over, but was left open between the Porte du Temple and the Porte St. Martin to receive the Sewer du Temple and the Sewer de la Croix; it then passed through the faubourgs of St. Martin, St. Denis, Montmartre, and Poissoniere, and was there partially covered over and planted with trees. It was left open again to receive the sewer of the Rue St. Lazare, and passing beneath Rue de la Chaussee-d'Antin, it penetrated through the Faubourg St. Honore, and the middle of the Champs Elysees, to fall into the Seine. Gradually the work of extending and improving the sewers was carried on, and in 1806 there existed about 79,700 feet covered, with the exception of 5200 feet. During the reign of Louis Philippe about 80,000 yards of additional sewers were made; but their usefulness was only partial, and the sanitary condition of the streets was bad in the extreme.

In 1855 the works which were to transform the whole system of sewage collection were commenced, the projects having been previously elaborated by the late M. Belgrand, Ingenieur des Ponts et Chaussees. At that time there were about 145,000 yards of sewers for 425,000 yards of streets, while at present there exist some 775,000 yards of sewers for 860,000 yards of streets. About 148,000 yards is the length of the service drains of the dwelling-houses. The system as now carried out is divided into two classes, the sewers and the collectors; the former receive the street and house

water, and conduct it to the collectors. The latter are constructed along the lower levels of the city to receive the natural drainage, as well as the contents of the sewers. They are three in number. The first is on the right bank of the Seine, and is known as the Departmental collector; it commences at the point of intersection between the Rue Oberkampf and the Rue Menilmontant, and passes under the old boulevards. Its course is broken by three bends, by which it crosses the basin of La Villette, the fortifications, and the Grande Route St. Denis, until it falls into the Seine, near the Ile St. Ouen. The sewage dealt with by this collector is of the worst kind, containing, as it does, the impurities from the abattoirs, gas works, the factories of La Villette, Montmartre, &c., and even the overflow from the Bondy depot. The second collector on the right bank of the river commences at the Arsenal basin, following the quays, and running under the Rue Royale, the Boulevard and Rue Malesherbes, it traverses the Route d'Asnieres and falls into the Seine above the railway bridge. At the Place du Chatelet it is increased to receive the contents of the collector of the Boulevard Sebastopol; at the Place de la Concorde the sewer of the Rue de Rivoli joins it; at the Place de la Madelaine it absorbs the sewer of the Petits-Champs, and at the junction of the Boulevard Malesherbes and the Rue de la Pepiniere, a sewer following the course of the brook of Menilmontant flows into it. On the left bank there is only one collector, which at its commencement absorbs the river Bievre, that at one time used to flow into the Seine above the Pont d'Austerlitz. The collector taking this stream runs behind the Jardin des Plantes, towards the Boulevard St. Michel, when it passes along the quays as far as the Pont d'Alma; here a double siphon takes it across the river, when the gallery passing under the height of Chaillot and the Avenue Wagram, crosses the village of Levallois-Perret, and joins the collector on the right bank last described, about 550 yards from the point of discharge. Near the Pont d'Alma on the left bank, it receives the Montparnasse sewer, and the Grenelle collector; on the right bank the Auteuil collector falls into it.

As an indication of the form and arrangement of the galleries, we may give a few particulars of the great collector on the right bank, the course of which has been already indicated. The section is a gradually increasing one to accommodate the discharge from the various tributaries flowing into it. The sewage water flows in a channel, on each side of which is a paved side walk, the whole being inclosed within a semicircular arch. The collector is composed of four different types, Nos. 6, 5, 3, and 1. The total length is 27,207 feet, and the lengths of the different sections are respectively 2296 feet, 2853 feet, 7019 feet, and 15,039 feet. Type No. 6 extends from the canal St. Martin to the Rue St. Paul; type No. 5 from that point to the Boulevard Sebastopol; type No. 3 from the Boulevard Sebastopol to the Place de la Concorde; and type No. 1 from this point to the discharge at Asnieres. Type No. 6 is 8 feet $2\frac{5}{8}$ inches wide at the point of springing of the arch, the height from the side galleries to the point of springing is 4 feet $11\frac{1}{8}$ inches, and the side walls are curved with a radius of 18 feet $9\frac{1}{8}$ inches; the width of the side galleries is $35\frac{1}{2}$ inches on one side, and $15\frac{3}{4}$ inches on the other, and the width of the channel is $31\frac{1}{2}$ inches. The depth of the channel in the middle is $15\frac{3}{4}$ inches, the invert being curved. The thickness of masonry is $10\frac{5}{8}$ inches inside the invert, the bottom of the structure being flat, 7 feet $6\frac{1}{2}$ inches wide. The thickness of the side walls and arch is 13 inches, and the interior of the sewer is covered throughout with a lining of cement $1\frac{3}{16}$ inches thick. The outside of the arch is also protected with cement. Type No. 5 is 9 feet $10\frac{1}{16}$ inches wide at the springing of the arch, the height of the side walls to springing is 4 feet $11\frac{1}{8}$ inches, and the radius to which they are curved is 12 feet $9\frac{1}{2}$ inches. The widths of the side walks are $27\frac{9}{16}$ inches and $19\frac{11}{16}$ inches respectively, and that of the channel is $47\frac{1}{4}$ inches. The depth of the latter is $31\frac{1}{2}$ inches in the center and $27\frac{9}{16}$ inches at the sides; the thickness of walls and arch is 13 inches, and the thickness underneath channel is $11\frac{13}{16}$ inches. The underside of the structure is flat and about 6 feet wide; this, like all the other sections, is lined throughout with

cement. Type No. 3 is 13 feet $1\frac{7}{16}$ inches wide at springing; the height from side walks to springing is $35\frac{7}{16}$ inches, and the side walls are curved with the same radius as the arch, so that the section of this type is more than a semicircle. The side walks are both $27\frac{9}{16}$ inches wide, and the channel is 7 feet $2\frac{1}{4}$ inches wide. The depth of the latter is $39\frac{3}{8}$ inches in the middle and $31\frac{1}{2}$ inches at the sides, the thickness of masonry under the channel is $17\frac{11}{16}$ inches and at the sides it is $23\frac{5}{8}$ inches. The under side of this section is curved on the exterior. Type No. 1 is 18 feet 3 inches wide at springing and 23 feet 7 inches wide on the outside of the masonry, the arch is elliptical and the height from springing to center is 6 feet 4 inches; the side walls are curved and are 3 feet 5 inches high from the side walks to the point of springing. The walks themselves are 2 feet $11\frac{1}{2}$ inches wide, and the width of the channel is 11 feet 5 inches. The depth of the latter is 6 feet 11 inches.

The normal distances between the underside of the masonry and the street levels are as follows for the different types except No. 1.

	ft.	in.
Type No. 3	16	$6\frac{3}{4}$
" No. 5	15	$10\frac{1}{16}$
" No. 6	13	$6\frac{9}{16}$

The gallery under the Boulevard Sebastopol may be taken as a type of one of the branch collectors. It was constructed between 1855 and 1858 under one of the side avenues of the boulevard from the Boulevard St. Denis to the Quai de la Mégisserie; from this point it extends with type section No. 6 under the Boulevard de Strasbourg, as far as the Rue du Chateau-d'Eau. In ordinary work this gallery serves as a collector for the flat district known as the Marais; during heavy rains it discharges the overflow direct into the Seine, and renders impossible the floods which used to be common in the Faubourgs St. Martin, St. Denis, Montmartre, &c. In this gallery are laid the two great water mains which receive their supply from the Ourcq. The following are the principal dimensions of the gallery:

	ft.	in.
Length	5074	0
Width at springing of arch	16	$0\frac{11}{16}$
Height from side walks to top of arch	11	$11\frac{5}{8}$
Width of side walks	2	$7\frac{1}{2}$
Width of channel	3	$11\frac{1}{4}$
Depth "	4	$3\frac{3}{16}$
Height of side walls	3	$11\frac{1}{4}$
Thickness of arch at crown	1	$7\frac{11}{16}$
" " springing	2	$11\frac{7}{16}$
Thickness of cement lining	0	$1\frac{3}{16}$
Distance apart of ventilators	164	0
" of street connections	328	0
Height of branch to street traps	6	6
Width " "	2	$7\frac{1}{2}$

The edges of the side walks of this gallery, as well as of all except the largest sections, are furnished with rails, along which the wagons run, which are employed for cleaning out the channels. These wagons consist of a light frame running on wheels and furnished with a movable dam turning on an axis in the wagon, and being manipulated by a winch. Its form corresponds to that of the channel. When it is desired to remove any obstruction in the channel the dam is lowered, backing up the water behind, which being suddenly released carries with it the accumulation of sand, mud, &c. For the larger sections, boats are employed instead of the wagons. These are built of iron, and carry a movable dam in front similar to that attached to the wagons. Projecting from the boat are two arms carrying guiding wheels, which pressing against the sides of the channel keep the boat in the center. When the dam is lowered the water behind it forms a head of from 6 inches to 12 inches, which is sufficient to produce the desired effect. The deposits accumulating below would quickly form a bank that would stop the progress of the boat, if the water in escaping through the spaces between the sides of the dam and the channel, and by small openings made in the former, did not drive the sand and mud constantly in advance of the boat. The rate of progress is very slow, as it takes from eight to ten days to traverse the five miles of the grand collector. In returning up stream movable dams are placed in the channel about every 600 yards, to reduce the speed of the current. Safety chambers for the workmen are placed at intervals of 650 feet. This precaution is very necessary, since in periods of heavy rains the collectors are

quickly flooded, as, for instance, on the 27th of July, 1872, when in five minutes the Sebastopol collector was filled to the roof, and several workmen were drowned. There are about 7000 points of egress for the workmen in case of necessity. The number of men employed in cleansing the sewers is about 700.

By means of the collectors nearly all the sewage water is discharged into the Seine far beyond the limits of the city. But this is done at the expense of the river lower down, chiefly on account of the great deposits of material held in suspension, since, as we have seen, the house sewage proper is not admitted into the collectors, but is removed from the cesspools by carts. Dredging operations are constantly necessary, and about 120,000 tons of *débris* are removed annually from the Seine, at a cost of some £6000. To obviate this evil, sewage utilization works have been established for some years on a comparatively small scale at Gennevilliers, and larger ones are now in contemplation.

A commission was lately appointed by the Prefecture of the Seine to examine into a project for the construction of irrigation canals which should take the sewage water from the collectors and distribute it upon suitable land in the vicinity of Paris, with the object of improving the soil and also to convert the impure waters into an effluent that might filter gradually into the Seine. It will be observed that this project is an extension of the sewage utilization scheme already carried on at Gennevilliers. The new project includes the construction of a main irrigation canal extending from Clichy to the Forest of St. Germains, of six secondary branches, and of a large number of channels which collectively should irrigate an area of 16,000 acres.

The total length of the principal channel would be about 18,000 yards. It would be circular in section, 6 feet 6 inches in diameter, and would traverse the Seine three times by siphons in cast iron. The pumping station would comprise five engines, collectively of 1200 horse power, of which two are already at work in pumping the sewage for the Gennevilliers' irrigation. The estimated cost for these works is £160,000 for the pumping station and irrigation canal, &c., £40,000 for the secondary branches, or £200,000 for all, not including the outlay made at Gennevilliers, which has reached about £65,000.

The sewage utilization works at Gennevilliers were commenced in 1869 upon 14½ acres of ground, and have gradually developed until at the present time about 600 acres are under treatment. This land receives about 600,000 cubic feet of water per acre per year. The use of this water is quite optional, no cultivator is obliged to take it, and each may use what quantity he wishes, and apply it in whatever way he judges best. There are no data indicating the quantity taken by each farmer, so that only the average results are known.

The irrigated soil is generally laid in ridges separated by trenches; the trenches receive the water, and the ridges are reserved for the plants. The vegetable crops are here in advance of all others, but a number of fields are occupied by potatoes, beetroot, cereals, lucerne, &c. When it is desired to have the soil less broken, it is only intersected by small trenches, generally parallel, and placed about 9 feet apart. The general appearance of the crops is most satisfactory. The vegetables, the quality of which has been much criticised, are excellent. The Horticultural Society of Paris, which has followed with the greatest interest the development of the sewage farm at Gennevilliers, has spoken of the success obtained in numerous reports. At the bottom of the open channels by which the sewage is distributed, there is a blackish deposit, formed by substances held in suspension, mineral and organic. At the moment of its formation, this deposit seems impermeable; but after having been exposed some time to the air, it has the appearance of a felt composed of hairs and vegetables and other *débris*. This deposit is left at the bottom of the trenches during one crop, and is afterwards worked into the ground. Stony ground, of which there is a considerable quantity in Gennevilliers, is much improved by the deposits of insoluble matters, mineral and organic, which the sewage waters leave on its surface, and the amount of fertile soil is thus gradually increasing from year to year.

The scheme for the extension of the

sewage utilization as elaborated by the late M. Belgrand, is as follows:

At present two 400 horse power engines raise part of the sewage water from the collector at Asnieres. Two other engines, established near the first pair, would be sufficient to pump the rest of the sewage. The invert of the St. Denis is at a much higher level, and could be discharged in the plain of Gennevilliers by gravity. From the pumping-station at Clichy to the forest of St. Germain, for a length of 16 kilometers, the water would be pumped through a main; this conduit would pass by the plain of Colombes, across the Seine, in a siphon, at the Island of Marante, would go through Bezons, Houilles, Sartrouville, then a second time over the Seine, and would enter the northern portion of the forest of St. Germain, where there are 3750 acres of sterile ground, which irrigation would fertilize; afterwards the water may be sent in a channel to Achères, where the irrigation would be extended over 1600 acres. The irrigable surfaces are approximately as follows:

	acres.
District of Gennevilliers.........	2500 to 3000
District of Nanterre, Colombes, Reuil.........................	2500 to 3500
Districts of Carrières, Bezons, Argenteuil, Sartrouville..........	3500
Forest of St. Germain...........	3700
District of Achères..............	1750

The largest of these territories, that of the forest, would be at the disposal of the municipal service, and would constitute an immense regulator, over which the waters would run, and by which irrigation of the other districts might be controlled. For this reason this large area constitutes one of the chief advantages of the scheme.

JAPANESE METHODS OF PROTECTING THE BANKS OF RIVERS.

By W. S. CHAPLIN.

Written for VAN NOSTRAND'S MAGAZINE.

THE Japanese have worked out original methods of protecting the banks of rivers. Perhaps the peculiarity of the circumstances in which they are placed has had much to do with this fact. The rivers of Japan are all, in the upper half of their courses, rapid mountain streams, but nearer their mouths they become sluggish and generally navigable. The valuable land of the country is that which lies low enough to be irrigated. Hence the struggle, which is everywhere apparent, to keep the streams in narrow beds and retain the soil on their banks for cultivation. In the lowland portions simple earthen dykes serve to hold the water; but, at the points where the rivers change from the rapid to the sluggish character earth would not resist their action. At these points we find the structures which are described below.

The simplest form used is a basket about one and a-half or two feet in diameter, and from six to thirty feet long. This basket is filled with the rounded pebbles, which are brought down by the river, and are from six to ten inches in diameter. The meshes of the basket are made small enough to keep these pebbles in. It will be seen that such a basket when filled possesses many characteristics which are valuable in engineering; they are made of bamboo, which is always at hand in this country, and are filled with such stones as every river furnishes; they adapt themselves to the bottom whatever its shape or the changes which take place in it, and they can be made by an ordinary laborer. Bamboo is said to decay rapidly when exposed to heat, but labor is so cheap, that, perhaps, it is as economical in the end as it would be to use a more durable and a more costly wood. In many places these baskets (the Japanese call them snake-baskets or stone-baskets) are used to protect the outside of earthen banks and are simply laid against them, one resting on another.

FIG. 1.

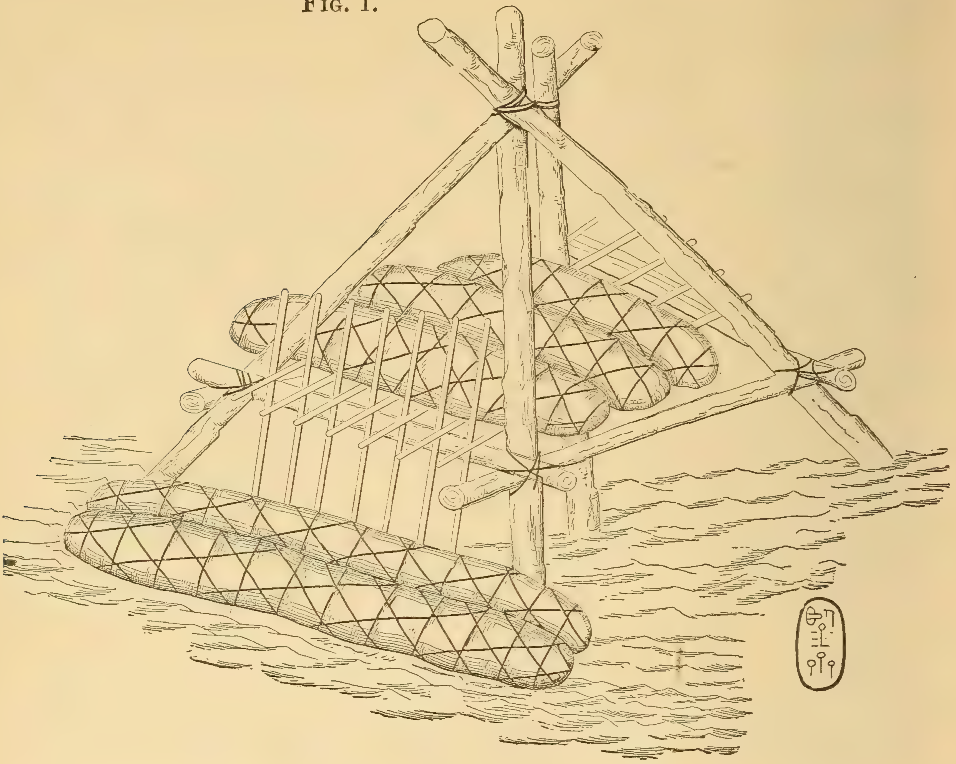


FIG. 2.

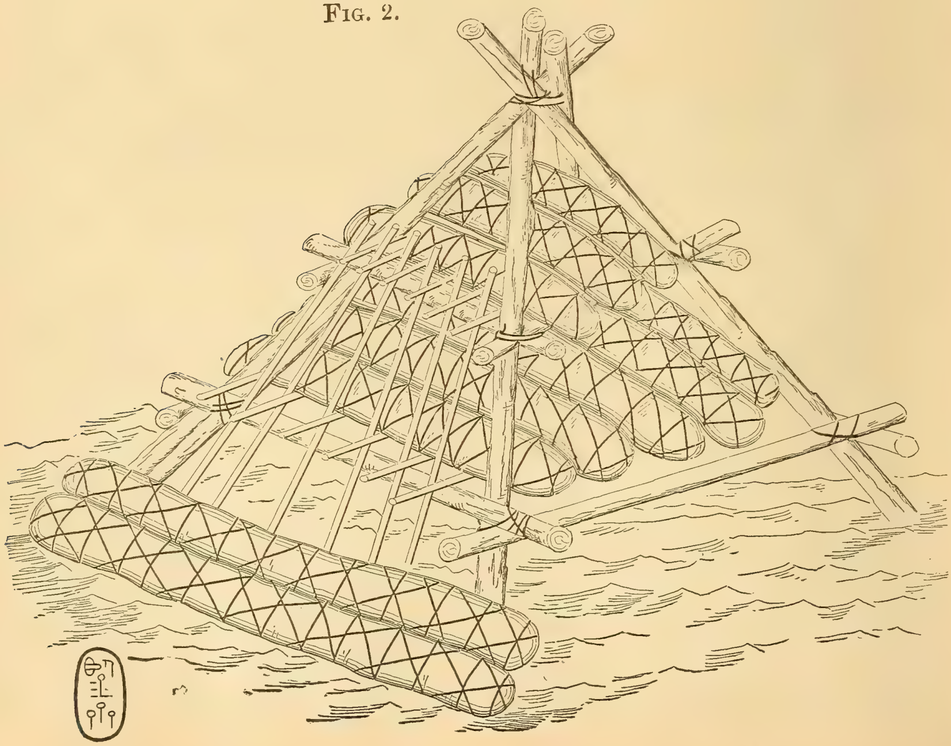


FIG. 3.

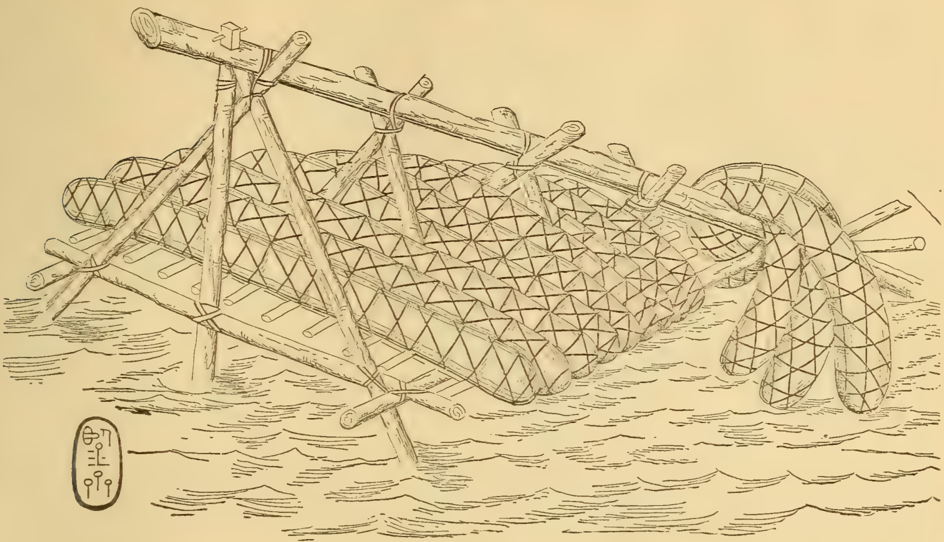
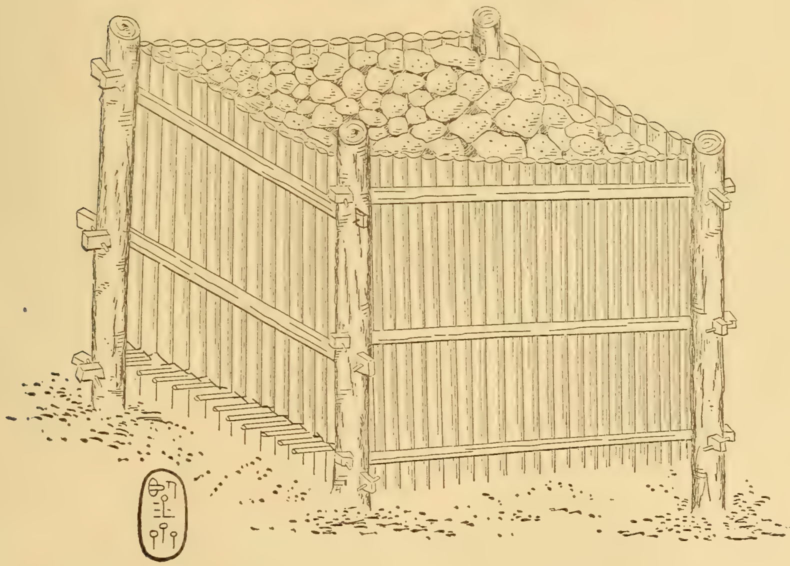


FIG. 4.



In such cases they are built or repaired during the dry season in the summer. Where a stronger current is to be resisted, the whole bank is made of baskets placed longitudinally, with a top layer laid transversely. When the exposed side needs repairs, another layer of baskets is built against it, thus increasing the strength of the bank at the same time.

To avert part of the current, but not all of it, the Japanese use such structures as are shown in Figs. 1, 2 and 3*. These trestles are made of logs about eight inches in diameter, lashed together with rough hemp ropes. Three or four feet from the bottom of the river there is a platform, on which is placed the load to keep the trestle in place. When the water is low these trestles have but little effect on its flow; but when it is high,

* The figures are from original drawings by a native Engineer.

FIG. 5.

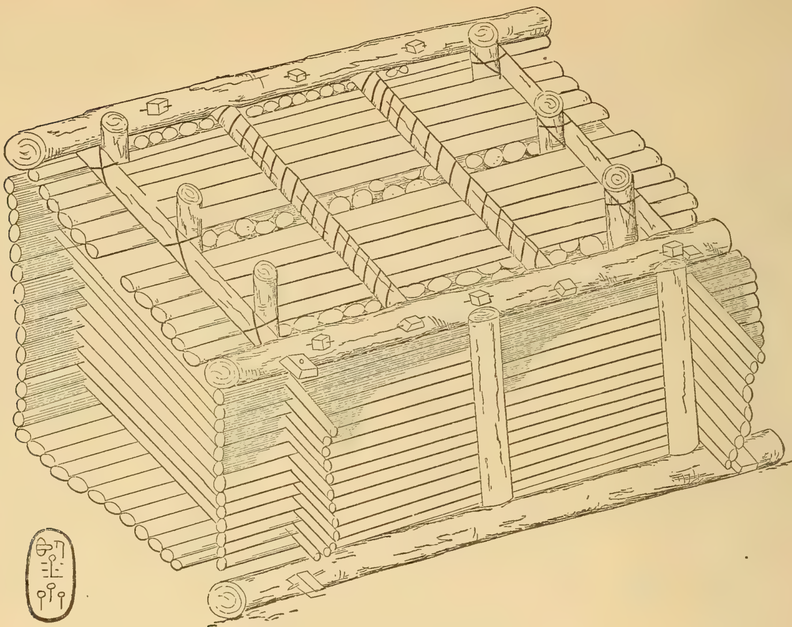
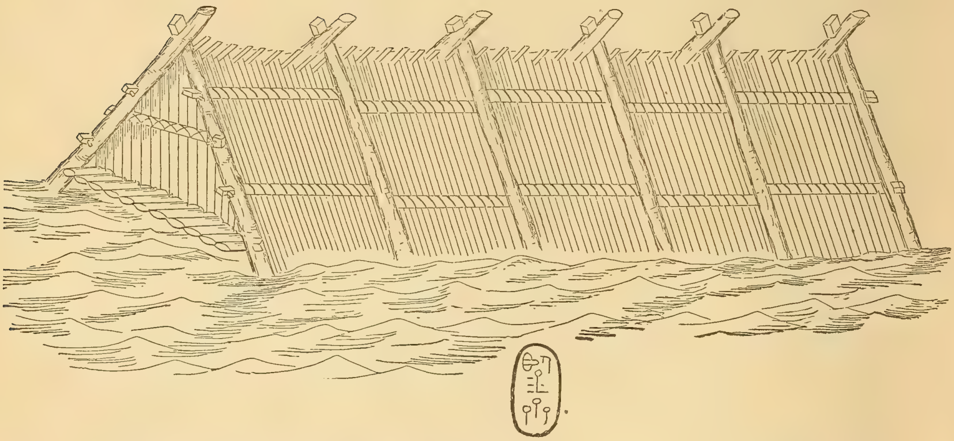


FIG. 6.



they turn away the force of it so that the bank is somewhat sheltered, while the velocity is not so reduced that a deposit is formed along the shore. To give still more protection long baskets are placed in front of the trestles as the figures show. Where the velocity of the water is very great the forms seen in Figs. 2 and 3 are used.

During low water a line of these trestles is sometimes transformed into a dam, in order to throw the water into irrigation canals. To do this long logs are placed at the water surface from one trestle to the next. Then bamboos are driven into the bottom along the logs about three feet apart, so that the river bottom supports the lower ends and the logs the upper. Mats are placed against the bamboos, and earth or sand is thrown against the bottom of the mats. Such a dam is very tight and effective until high water comes; when the mats and bamboos are carried down stream, the logs, being fastened only at one end, swing around into the line of the current and

all possible space is left for the flow of the water. Bamboo is very generally used in all constructions for bank improvement; but other woods are used where greater strength or framing is necessary. Iron is never used, but all connections are either made by lashing or by mortices and tenons and pins. Figs. 4 and 5 show two common forms of crib work; that shown in Fig. 4 is adapted to soft bottom, and that in Fig. 5 to rocky bottom. In both forms there are platforms at about half their height above the bottom, on which the loading stones are placed.

Fig. 6 shows a peculiar form of crib work. The frame is made of logs, and the sides are filled in with bamboos which are lashed to the cross pieces.

THE TRANSMISSION OF MOTION TO A DISTANCE BY MEANS OF ELECTRICITY.

By M. CADIAT, Engineer.

Translated from "La Nature" for VAN NOSTRAND'S MAGAZINE.

THE employment of electricity for the transmission of motion to a distance is an accomplished fact. For some months, I have controlled the machinery of a workshop, situated some distance from the motor, with only such connection as was afforded by a conductor of an electric current.

The Société du Val d'Osne owns an electroplating establishment at Paris, in which copper-plating is constantly in progress. The electricity was furnished by a Gramme machine, which was run by a portable engine at considerable expense and trouble.

The idea of using two Gramme machines suggested itself to me. The machines have, heretofore, served for lighting the shops in winter. Machine No. 1 was attached to the horizontal shaft at the millwright's shop. This was the *generator* of the electricity. The second was placed in the electro-plating shop, 150 meters distant. This was the *receiver* of electricity. The two machines were connected by a double wire. The current received at the second machine was transformed into work, by which the electro-plating machine was kept in motion.

It is a month since the plan was put in operation, and there has been no irregularity in its working. No superintendence is necessary. The arrangement is as simple as can be desired, and the motion is started or stopped by simply connecting or disconnecting the conducting wire.

One advantage of the system lies in the ability to vary the velocity of the receiving machine. It is accomplished by varying the resistance of the conducting wire. Thus the velocity of the machine No. 2, being 750 revolutions, if a copper wire two meters long, and one-and-a-half millimeters in diameter, be introduced into the circuit, the velocity is reduced by forty revolutions. If an iron wire of one-and-a-half meters in length and $\frac{8}{10}$ of a millimeter in diameter be used, the velocity is reduced by 100 revolutions.

When the portable engine was employed to run the electro-plating machine, the expense was about twenty-four francs per day. Now the cost is inappreciable. For if there is any extra consumption of fuel in the driving engine at the millwright's shop, it is not noticeable, and the engineer cannot detect the stopping or the starting of the Gramme machines by any irregularity of his motor, which is only a ten horse-power engine.

When the No. 1 machine is employed for lighting purposes, it absorbs a sensible amount of the power of the engine. It is estimated to require in general two horse power for its successful working.

This is certainly not the last that is to be said upon this question. We have employed two machines used for lighting and not designed for the purpose for which they are employed. We do not flatter ourselves that we have obtained a maximum result.

Should the two machines have the

same or even similar dimensions? Ought the first to possess higher tension or greater quantity than the second?

These questions are yet to be answered. At present we are content to announce that the transmission of motion to considerable distance by an electric current is a practical possibility.

WOHLER'S EXPERIMENTS ON THE STRENGTH OF GIRDERS AFTER REPEATED CONCUSSIONS AND STRINS ON IRON BRIDGES.

By Dr. E. WINKLER, Professor of the Polytechnic School at Vienna.

From Foreign Abstracts of Institution of Civil Engineers.

The Author discusses the results of Wohler's experiments on the effect of repeated strains and blows on iron, and attempts to apply these results to iron girders, most of Wohler's trials having been made on axles and tires. The Author points out the empirical nature of the present calculations for wrought-iron bridges, showing that the most elaborate analytical work is in practice nullified by the fact that the immediate effect of the blows received by a girder from the moving load, as also the ultimate effect of these blows lasting for years, have not yet been expressed in a mathematical form, and have not been introduced in the usual formulæ. The consequence is that engineers have been obliged to assume so large a margin of safety that accurate calculations of the cross sections of iron are to some extent useless; for, the effect of the forces above mentioned not being ascertained, the bridge may be a great deal too strong, or even not strong enough. After alluding to the great increase in the weight of locomotive engines in the last ten years, which has diminished the margin of safety in the old girder bridges, Dr. Winkler considers the effect of the permanent load in comparison with that of the passing trains, and comes to the conclusion, that the heavier the girder, the less will be the immediate as well as the ultimate effect of the moving load on the iron: in other words, the margin of safety should be greater for bridges of small span than for large ones. Messrs. Klett and Co., of Nurnberg, have constructed many bridges in Germany, on the principle that the admissible strain per square inch on wrought iron should be $3\frac{3}{4}$ tons per square inch for bridges of 30 feet span, increasing to $4\frac{3}{4}$ for 250 feet span, and to $5\frac{3}{4}$ tons for 460 feet. The Author then proceeds to consider the ultimate effect of repeated strains without shocks, such as are produced by a passing train, and explains why he thinks Wohler's results on axles to be applicable to girders. The rules he deduces are the following:

1. Fracture occurs sooner, *i.e.* through a less strain per square inch, if a load is removed and frequently reimposed, than if the same load is permanent.
2. The less the strain produced by the moving load, the oftener must it be removed and brought on again before producing fracture, *i.e.* the longer will the girder last.
3. The number of separate loadings required to produce fracture is greater, in the same ratio as the maximum strain is greater.
4. If the maximum strain of a moving load never reaches a certain limit (which Launhardt calls "work-strength"), fracture will never occur.
5. This "work-strength" is larger if the strain produced by the permanent load is larger.

Wohler's experiments, which lasted from 1859 to 1870, were continued by Professor Spangenberg at Berlin up to the year 1873, and the above laws were confirmed. The Author adds tables showing the calculated strains and those resulting from experiments, the differences being but slight. The Author also attempts to establish a mathematical curve for the "work-strength," and compares it with others calculated by Gerber

and Launhardt. He next considers the effects of repeated moving loads on the resistance to compression, the previous work having applied to tension only. The experiments made in this respect are hardly sufficiently numerous; but with the results arrived at, the effects of moving loads often repeated but without concussions or blows are gone into, the cases of tension only, compression only, tension greater than compression, and compression greater than tension, being all separately considered. Having established rules for these cases, the Author discusses the effect of repeated blows, which he compares to a weight equal to that on the driving wheels of a heavy engine falling through a height h; he again, however, repeats that the experiments are as yet incomplete, and do not prove that the effects of the shocks of an engine are really similar to those of a weight falling on the girder. An investigation of these effects on a girder already strained by the moving (but not striking) load, as described in the previous section, then follows, and all the cases of compression and tension, and both, are separately considered, the conclusion being that the actual strain which obtains by the rapid passing of a heavy engine is greater than the strain resulting from the calculation of the moving load alone in the proportion of about 1.3 to 1.0, while it only affects the permanent load in small spans.

The extreme proof-strains habitually placed on girder bridges to test them are condemned; and an abstract is given of the methods hitherto pursued by Gerber, Launhardt, and others for calculating the effects of moving or "striking" loads.

THE ATMOSPHERE CONSIDERED IN ITS GEOLOGICAL RELATIONS.

By EDWARD T. HARDMAN, F.C.S., H.M. Geological Survey of Ireland.

From "The Quarterly Journal of Science."

The gaseous envelope which surrounds our globe plays a very considerable part in the chemical changes ever going on in rock formations, whether actually at the surface—as in what is called the "weathering" of rocks—or in the less apparent, but perhaps more powerful, action carried on at greater depths, whither the atmospheric gases are conveyed by the action of percolating water. It has been shown by the experiments of Prof. Rogers, as well as by those of Bischof and others, that perfectly pure water has a very appreciable solvent effect on rocks and minerals; and that its power is immensely augmented, and capability to produce even more momentous alterations in the form of chemical decomposition added, when it is charged with carbonic acid, oxygen, nitric acid, and other matters derived directly or indirectly from the atmosphere.

While on the one hand, the influence of the atmosphere disintegrates and destroys rock-masses, on the other it is mighty in building them up. Without the small percentage of carbonic acid contained in air—a quantity relatively minute, but in the aggregate enormous—there could be no vegetation. The vegetable kingdom, which obtains its supplies of carbon from those insignificant traces, would be wanting, and there could be none of the coal-beds which form such important members of our rock-formations. This is a direct and palpable case. But if we consider the immense masses of limestones which have been accumulated from those of the Laurentian period, and for aught we know before it, up to the coral reefs of the present day, and which must owe their being indirectly to carbonic acid of former atmospheres, we shall have some idea of the stupendous results attained by very small means, provided time enough be granted.

A drop of rain water absorbs a trace of carbonic acid from the atmosphere, falls on a rock containing lime in some

form, dissolves the lime as bicarbonate, carries it down to the ocean, and finally gives it up to become part of the skeleton of a coral or mollusc, which in its turn may form a portion of an immense mass of limestone rock.

The atmosphere mainly consists of a mechanical mixture of oxygen and nitrogen; these, however, bear to each other an almost constant proportion, any variations being extremely minute. The composition by volume is found to be as follows:

Oxygen	20.80
Nitrogen	79.20

Carbonic acid,* 3 vols. to 10 vols. in 10,000 vols.

Ammonia, a trace; 0.1 to 135 vols. in 1,000,000.

Nitric and sulphuric acids, traces occasionally.

The respective amounts of oxygen and nitrogen do not vary to the extent of as much as 1 per cent., even in exceptional cases. Regnault's analyses of samples of air collected in various parts of the globe gave very close results, the percentage of oxygen being to all intents and purposes identical, viz., 20.9 per cent. Air collected by Sir James Ross in the Arctic Regions did not differ in this respect from that collected at Paris, or at Ecuador in South America; the very slight differences that have been observed not exceeding those noticed in air collected at the same place at different times: and the same results have been obtained from air collected at the summit of Mont Blanc, and even from that taken at a height of 21,000 feet by Gay-Lussac during a balloon ascent. There is, therefore, a marked uniformity in aerial mixture under all circumstances.†

It has not yet been explained how it is that a mere mechanical mixture should have this constant composition, but it is certain that the gases are not chemically combined—

1. Because the proportion of the constituents bear no simple relation to the atomic or combining weights of those elements.
2. When they are mixed in the proper quantities there is no contraction, nor is there any evolution of heat, and the mixture acts in every way as air.
3. Water through which air is passed dissolves the two gases in very different proportions to those in which they are associated, the oxygen being very soluble, while the nitrogen is not taken up to any notable extent.

CARBONIC ACID.

Although the bulk of the atmosphere is made up of the two gases just referred to, these do not take so active shares in geological matters as the almost infinitesimal trace of carbonic acid present. This, then, deserves the place of honor in the following pages, and it will be seen that there is a great deal to be said about it. We shall, therefore, defer the consideration of the behaviour of the other constituents for a little while.

The amount of carbonic acid ranges from about 3 to 10 volumes in 10,000 volumes of air, and the proportion varies between these limits in different localities, owing to many modifying causes. In the neighborhood of towns or cities it will be much increased by the combustion of fuel, the exhalations of animal life, and the decay of organic matters. In the vicinity of large forests, swamps, and fens, vegetable decay will also augment it, though at the same time the living vegetation there will help to reabsorb it, or, to speak exactly, to decompose it. Near volcanoes the air will be more or less impregnated with it; and from many mineral springs, and subterranean caves and fissures, a very considerable quantity of this gas is discharged into the atmosphere. The percentage of carbonic acid also varies slightly between day and night.

GEOLOGICAL EFFECTS.

So small a trace as even 10 in 10,000 —taking the maximum at only 0.1 per cent.—certainly does not at first sight seem capable of performing any very great geological work; but we must

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* Strictly carbonic anhydride; but I shall use the less scientific but more familiar term in this paper to designate it, in accordance with geological custom as regards this gas. Indeed, in its geological relations it may be regarded as a true acid when dissolved in water.

† From some recent observations, by Boussingault and Miller, it would appear the amount of oxygen slightly differs at various heights. Mendeleeff thinks Gay Lussac's results are probably incorrect (*Bull. Soc. Ghim.* [2], xxv., 394). However, we have hardly decisive information yet on this point.

recollect that the vast quantities of existing vegetation are entirely dependent on the carbon they obtain from the atmosphere, and the decay of vegetation, and consequent liberation of carbonic acid, has a very powerful effect in the alteration or solution of rocks. However, the direct action of atmospheric carbonic acid on rocks—both as a destructive and as a recuperative agent—must be anything but small, even at the present day. As to the latter, it is only necessary to refer to the immense coral reefs now being formed, while the widespread deposits of ooze and mud over the floors of the Atlantic and Pacific are largely due to carbonic acid entrapped by rain water and carried down into the ocean. On the one hand, the carbonate of lime previously conveyed by river waters is held in solution, and kept in a fit state for assimilation by marine organisms. On the other, the dead shells while sinking through great depths are attacked, forming, as Sir Wyville Thomson tells us, if the depth is not sufficient to give time for complete decomposition, a calcareous ooze; at greater depths the deep sea muds.* Thus a very great amount of the carbonate of lime in the ocean owes its existence entirely to atmospheric carbonic acid, either from the direct action on calcareous rocks, whether old limestones or silicates,—or indirectly through a series of changes whereby carbonate of soda would be produced, and this being brought into contact with the chloride of lime so abundant in the ocean, carbonate of lime would result. There can be no question but that such effects are going on extensively day by day.

INFLUENCE OF VEGETATION.

If we follow the series of rock-metamorphisms, due to the simple absorption of carbonic acid by a plant, the result will be seen to be more than interesting. The carbon is assimilated by the plant, an equivalent of oxygen being exhaled. The plant dies, and may become either a part of a coal bed or may be separately imbedded amongst layers of sediment of some kind. Slow decomposition will now set in, sooner or later, and, if there be a reducible compound near it, chemical changes result. Say the strata contains sulphate of iron: this is reduced to sulphide, commonly known as iron pyrites, a very common mineral in coal seams—as colliery owners know too well—or in other strata where plants abound. The reduction is effected by the carbon of the plant abstracting the oxygen from the sulphate, and the resulting carbonic acid either is taken up by percolating water, and penetrates farther into the heart of the rock, effecting new changes, and producing carbonates, or it finds its way to the surface through some crevice or by the aid of a mineral spring, and once more mingles with the atmosphere, to be perhaps again absorbed by vegetation, and pass through a round of similar changes afresh. Carbonic acid exhalations are very abundant at the surface of the earth, and are in great part ascribable to the oxidation or decay of organic matter which in the first instance derived its carbon from the atmosphere.

The above case shows the result of slow decomposition at great depths; but similar effects are induced by the decay of organic matter near or at the surface. In swampy grounds, lagoons and deltas, such as those of the Mississippi and the Sunderbunds, the decay of organic matter must exercise a very powerful influence on the chemistry of the soils, rocks and sediments with which the water charged with the compounds formed during the process of rotting comes in contact. Peroxides, such as those of iron and manganese, will be reduced to the proto state, and will be rendered soluble and carried away in solution, to be after a while re-oxidized and deposited in such masses as to be worth working as ores. Silicates of soda, lime and magnesia will be decomposed, and removed as carbonates; and sulphates, which are usually present in most waters, will be reduced first to sulphides, and eventually decomposed with evolution of sulphuretted hydrogen. Such a process as this may be observed every autumn in the North of Ireland during the maceration of the flax plant, which is placed in pits filled with water, and, being allowed to remain for some weeks, the softer tissues are rotted away, leaving the fibers fit for

* It now appears, however, that a considerable portion of these muds is derived from the gradual disintegration of pumice and other volcanic *débris* very widely spread over the sea-bottom. See Mr. John Murray's paper on the "Distribution of Volcanic Débris" (Proc. Roy. Soc Edinb.). The result is still due, however, to the action of carbonic acid dissolved in the ocean.

manufacture. The stench of sulphuretted hydrogen from the decomposing flax is almost unbearable. Having analyzed the mud which subsides to the bottom of the flax-pits, I find that the reducing power of the rotting tissues are as described above. The clay in which the pits are sunk contains nearly all the iron present in the ferric condition when not subject to the action of the plants, but in the mud from the bottom there are only proto-compounds, the iron mostly as carbonate. Nor is there a trace of peroxide of iron in the flax-water, but, on the contrary, plenty of ferrous iron.

Clay-Ironstone.— After this fashion must have been formed the clay-ironstones of the coal-measures. The great swampy estuaries of that period may be regarded as gigantic flax-pits; and the rotting vegetation not only altered other salts and compounds of iron to carbonates, but prevented the oxidation of such carbonate of iron as might have been carried down in solution, until in course of time it also was precipitated along with the clayey sediments.

During such changes near the surface a very large proportion of carbonic acid is returned to the atmosphere. And that there must be, and always has been, this constant circulation of carbon between the earth and the atmosphere is self-evident. What time it originated must be beyond our ken, but, so far back as we have any knowledge of, there are evidences in the rocks of vegetable or animal life. And the decomposition of such carbonaceous matters, whether at the surface, immediately after death, or whilst buried under a depth of strata,—as in the case of coal-seams,—has always yielded carbonic acid to the atmosphere. At the same time the carbon returned in this way falls far short of what has been abstracted. But, as Bischof points out, the carbon acts as a carrier of oxygen between the mineral kingdom and the air.

FORMERLY GREATER ABUNDANCE OF ATMOSPHERIC CARBONIC ACID.

It has long been considered probable that in remote ages the proportion of carbonic acid was greater than it now is, more especially during the Carboniferous Period. The remarkable luxuriance of vegetation of a tropical *facies* during that era, in every part of the globe,—even the polar regions,—indicates a very warm climate universally, and it is also thought to imply a much larger supply of carbonic acid than is now noticeable in the atmosphere. The rarity of warm-blooded animals has been pointed to as a corroboration of this view; but strictly this is only negative evidence, the absence of fossil forms affording no proof as to the non-existence in by-gone time of animals of any particular type. However, a very curious fact bearing on the question has resulted from Prof. Tyndall's researches on radiant heat. It appears that a very small addition of carbonic acid to air renders it absorptive and retentive of radiant heat, and a slight increase in the percentage of carbonic acid in the atmosphere would have a very distinct result. The visible rays of the sun could pass through the atmosphere to the earth; but the radiant heat from the earth, instead of being dissipated into space, would be imprisoned by the atmosphere, which would thus form a warm envelope around the earth, converting it in fact into an immense green-house. The glass roof of a conservatory acts in precisely the same way: it permits the solar rays to penetrate freely, but absorbs and cuts off the escape of the radiant heat, and the interior temperature is thereby rendered tropical. Granting, then, the former abundance of carbonic acid, the extreme richness of the carboniferous vegetation, its tropical character and wide distribution are very fairly accounted for. I shall show presently that there are other grounds for the supposition that the carbonic acid is now much less than it has been in these far back periods; nor is it to be considered that it reached its maximum even in the carboniferous age. It is true that the earlier formations afford nothing like such a superabundance of fossil plants; but this has been well accounted for by Dr. Sterry Hunt. He has shown that the vast amount of chemical action that has taken place in the reduction and accumulation of the metalliferous deposits of the older Palæozoic rocks will readily account for the scarcity of fossil vegetation in those rocks. To the decay of plants and the reducing action of the resulting carbonic acid those deposits must be in great measure attributed; and

their existence proves that an abundant flora flourished. The manner in which this chemical action takes place will be explained further on. I shall just quote Dr. Hunt's words on this point:—"Where are the evidences of the organic material which was required to produce the vast beds of iron-ore found in the ancient crystalline rocks. I answer that the organic matter was, in most cases, entirely consumed in producing these great results, and that it was the large proportion of iron diffused in the soils and waters of these early times which not only rendered possible the accumulation of such great beds of ore, but oxidized and destroyed the organic matters which in later ages appear in coals, lignites, pyroschists, and bitumens. Some of the carbon of these early times is, however, still preserved as graphite, and it would be possible to calculate how much carbonaceous material was consumed in the formation of the great iron-ore beds of the older rocks, and to determine of how much coal or lignite they are the equivalents." *

If we also reflect that the enormous quantities of lime-stones which are found in the older formations have been largely dependent on the carbonic acid of the atmosphere—in effect, the further we retrograde towards a primitive condition of things the more directly such carbonic acid must have come into requisition for such purposes, as there would be the less of it stored up in rocks, to be re-utilized as at the present day, when much of the carbonate of lime in waters is obtained by the disintegration of pre-existing limestones—and remember also the carbon that was required for the teeming animal life of ancient times, we shall see that there could have been no lack of carbonic acid; and it becomes a matter of small difficulty to accept the theory that a retrogressively greater proportion of carbonic acid gradually leads back to a primitive atmosphere in which that gas —as well as perhaps other gaseous acids, such as hydrochloric acid—was very abundant.

In regard to this question as to the increase or decrease of carbonic acid, a variety of very interesting points suggest themselves, and the facts almost altogether seem to range themselves on the side of a progressive decrease of carbonic acid. It seems certain that the amount of carbon stored up in the recesses of the earth very far exceeds that of the entire quantity combined as carbonic acid in the air. It is true that Liebig supposed the carbon so combined, which he calculated to reach 2800 billions of pounds, equal to about 1,250,000,000,000 tons,—figures and tons will probably aid in a better conception of this enormous weight,—to be far in excess of all the carbon stored up in coal-beds, and in plants on and in the globe. But this will hardly be subscribed to when we remember that the coal of the British Isles alone, as estimated by the late Coal Commission, is about 195,000,000,000 tons (I have added about a third for waste, &c., deducted in the original estimate). The carbon in this will weigh about 146,000,000,000 tons, taking an average of eighty per cent. But this was only calculated for coals fit for use, of not less than one foot thickness, lying at no greater depth than 4000 feet. Now if we include all the coal of inferior quality, of less than one foot thick, and at greater depths than 4000 feet, and then throw into the balance the enormous supplies of coal of the rest of the world and of the older and newer formations, not to speak of the highly carbonaceous shales, slates, schists, and clay ironstones, I think—even taking only this branch of the subject—we should rather be led to agree with Bischof, who, on the other hand, calculates that there is at least 6620 times as much carbon in the earth as Liebig has estimated for the atmosphere;* and Bischof's calculation is based on the very moderate assumption that the average proportion of carbon in all rocks is at least 0.1 per cent., which he considers—and no doubt justly—must fall far short of the real amount. This being so, it would certainly appear that there has been more carbon accumulated in the earth than has been restored to the atmosphere by decomposition, and that therefore the quantity of carbonic acid in the air has been gradually lessening from remote periods up to the present time. This

* "On the Origin of Metalliferous Deposits."—Chem. and Geological Essays, p. 229.

* Bischof, Chem. Geology, vol. i., p. 204. Dr. Sterry Hunt has also estimated the amount of carbon secreted in the earth as far beyond that contained in the present atmosphere,

appears anything but improbable, remembering the arguments already noticed in favor of the supposed highly carbonated atmosphere of the carboniferous period; and although the calculations leading to such a conclusion are necessarily based on very imperfect data, it may be safely affirmed, at least, that such a state of affairs is not only possible, but probable.

In these calculations we are not only to consider the carbon of the vegetable kingdom, for it will be obvious that any *animal* carbon which may remain in rocks is also more or less directly derived from the carbonic acid of the atmosphere. Taking the extreme case of the *Carnivora*, it is clear that they must ultimately depend on the air for their supplies of flesh-forming material. Say a tiger dines off a cow; the carbon and nitrogen of her flesh have been obtained from vegetation, which in turn extracted them from the air; so that we have a kind of physiological "House that Jack built." "This is the Tiger that ate the Cow that devoured the Grass that absorbed the Carbon," &c. Viewed in this way it seems that "living on air" is a more substantial kind of existence than has usually been supposed.

Now this which is true of the higher animals applies equally with regard to lower forms. There will be a vegetarian somewhere to fall a prey to a carnivorous marauder, who in his turn may be the victim of a stronger individual; and the successive appropriations may go through any number of steps. Thus the carbon and nitrogen of forms of animal life now fossil have been also derived from the atmosphere. We do not find much, if indeed any, of this carbon in its original form now, or directly traceable to animal agency, because highly nitrogenous organic substances decay very rapidly, but it is not unlikely that their results are to be seen in carbonaceous and bituminous shales, and oleiferous rocks such as those in the neighborhood of petroleum springs; for, as Dr. Sterry Hunt remarks, since animal tissues contain the elements of cellulose, plus water and ammonia, they may give rise to similar hydrocarbonaceous bodies to those derived from vegetable substances.*

In many cases, also, the decomposition of these animal tissues would result in the formation of carbonates, so that on the whole there must be, through this source, a vast quantity of carbon—originally drawn from the air—locked up in the crust of the earth. And to all must be added the immense amount of carbon combined as carbonate of lime due to the direct solvent action of atmospheric water on calcareous rocks and minerals. If we add all this to the vegetable carbon already considered, there can hardly be a question but that the amount of carbon abstracted from the atmosphere and hidden away in our globe very, very far, exceeds the proportion present in the air of this age. If this be granted—and I cannot see any possible evasion of it—we must admit that the more ancient atmospheres contained far more carbonic acid than that which now envelopes us, and must renounce the doctrine of Uniformity in this connection at any rate.

ORIGIN OF CARBONIC ACID.

Having got so far, we are naturally led to inquire as to the origin of the carbonic acid in the first instance. Carbon is so thoroughly associated in our minds with organic matter, or in fact with *life*, that it is difficult to conceive the possibility of its existence in an azoic world, and the difficulty is aggravated by the recollection that the earth must have been at the beginning in a state of incandescence, not to go further and say a gaseous condition. However, under the influence of extreme heat, many elements are isolated which at lower degrees of temperature—but still very great—combine and form chemical compounds. For example, hydrogen and oxygen at a high temperature unite to form water, but at a still higher are again dissociated, and we know that hydrogen exists in a state of incandescence, not combustion, in the sun's photosphere.† Similarly free carbon might have been one of the gaseous constituents of the earth in its nebulous phase,‡ and as the temperature lowered might have been consumed, or united with oxygen, and gone to form part of the primeval atmosphere. In

* Chem. and Geol. Essays. "On Bitumens and Pyroschists," p. 179.

† Prof. Henry Draper has just announced the discovery of oxygen in the sun. *Nature*, August 30, 1874.

‡ According to Mr J. Lawrence Smith, carbon in the gaseous form is spectroscopically manifest in the attenuated matter of comets. *Am. Journ. Sci.*, June, 1876.

this way all the carbon now in the crust of the earth would necessarily have been at first confined to the atmosphere. Then when rains began to fall, the carbonic acid, being carried down upon the earth, would soon decompose the silicates which must have resulted from the cooling down of the original heated mass; carbonates would be formed and carried down into the primitive oceans, and clayey residues would be left behind.

In course of time, when vegetable and animal life had made their *début*, the withdrawal of the carbonic acid from the air must have proceeded much more rapidly, and the atmosphere gradually cleared to such a condition as to permit of the existence of air-breathing animals. It may be here remarked that the very gradual introduction, in more recent periods, of warm-blooded beings, would also coincide with the hypothesis of the originally highly mephitic state of the atmosphere.

CARBONIC ACID NOW INCREASING OR DECREASING?

An important question now arises—Is the amount of carbonic acid increasing or decreasing, and what may the result be in either case? To begin with the last part of the question:—Any considerable difference one way or the other must result in a diminution of animal life: in its higher forms in the former event, in all divisions in the latter. Beyond a certain proportion very little above the ordinary standard—at most ten times, equal to about five vols. in 1000,* or 0.5 per cent!—carbonic acid in air becomes a deadly poison to all warm-blooded animals. On the other hand, a diminution in the percentage of carbonic acid would tell even more severely. Vegetable life would languish, graminivorous animals would eventually have nothing to eat, and, finally, the Carnivora, being obliged to prey upon each other, would of course become extinct. And this would be applicable to all divisions of the animal kingdom. The result would be a completely barren and desolate planet, perhaps in some degree resembling the moon. Doubtless that planet has passed through phases of existence alike to those which have obtained upon the earth; and Mr. Proctor† is of opinion that the moon certainly had originally an atmosphere, which is now either altogether absent or is attenuated to an extreme degree. It can well be imagined that this result, and its consequent azoic addition, has been brought about by some such absorption of the constituents of the moon's atmosphere as that which I have endeavored to sketch out above as regards the earth.

PPOBABLE WITHDRAWAL OF OXYGEN.—It may seem a little paradoxical that such dire effects would more immediately follow the withdrawal of a poisonous gas, and that the latter is on the whole more important to the continuance of life than oxygen gas, which is almost inseparable from our ideas of existence; but it is undeniable that such would be the case. The blood requires to be oxygenated, but in the absence of carbon there would be no blood at all. All this leads us to another point. The disappearance of carbonic acid must be followed after a period by the withdrawal of oxygen itself. It would gradually be carried by water into the interior of the earth, from which it could make no return, for it would be seized upon by compounds capable of oxidation, and its retreat in the form of carbonic acid would have been cut off.

As to the first part of the question, however, we have as yet no data for its solution. There are several means by which carbonic acid is supplied to the air, and many by which it is removed; but we are not in a position to determine on which side is the predominance, or whether there is at present a balance of power. The principal sources of increase are

1. Volcanic and other subterranean exhalations.
2. Respiration of animals.
3. Combustion of fuel, &c.

Respecting this last it should be pointed out that we are now restoring to the atmosphere some of the vast quantities of carbonic acid abstracted from it during the Carboniferous period, and imprisoned for ages in the interior of the earth in the forms of coal and clay-ironstone. Perchance by the time we have made an end of our supplies of coal a

* Watts, Chem. Dict., 1862, vol. i., p. 438.

† Quart. Journ. Science, July, 1874. "On the Past History of our Moon."

very sensible difference will have been effected in our atmosphere.

The absorption of the carbonic acid is brought about thus:

1. By vegetation, as already explained.
2. By the agency of marine organisms which secrete carbonate of lime.
3. By the direct action of atmospheric carbonic acid upon rocks, resulting in the formation of carbonates.

How far these antagonistic processes check each other cannot be conjectured. In order to arrive at any conclusion on the matter we should require to compare trustworthy analyses of air taken at frequent intervals during some thousands of years at least. We have yet no recorded analyses of it older than forty or fifty years. Probably in the remote future information will have been accumulated sufficiently to allow of the solution of the problem; and perhaps in those far distant times a Royal Commission, or some such form of Public Inquiry, will be solemnly convened to deliberate as to the possible duration of "Our Carbonic Acid Supplies." But should a necessity ever arise, it is comforting to reflect that it is not likely to occur until some ages after the traveled New Zealander has been gathered to his fathers, and even the very sites of Auckland and Otago perhaps long a subject of curious speculation amongst Central African *savants.* I say it is comforting to take this to heart in these days of sensational cosmogony, when one day we are threatened with destruction from the sweep of a comet's tail, and the next an unfavorable eruption of sun-spots may entail unheard-of miseries upon us. All the information we are in possession of goes to show that the trifling changes that are now observed in the condition of the atmosphere would perhaps require a continuance throughout many millions of years before making themselves disagreeably apparent.

GEOLOGICAL INFLUENCE OF OXYGEN.

This comes next in importance as a geological agent.* I have dwelt first upon the results wrought by the carbonic acid, because the work done by it is immensely greater in proportion to its amount. But oxygen also has its mission. Percolating the rocks, dissolved in rain-water, which is able to absorb a very large quantity of it, it quickly reacts on all oxidizable substances. Carbonates and proto-salts are converted to peroxides ; sulphides are changed in sulphates, and sometimes this is accompanied by the production of double salts, such as alums. A familiar instance may be referred to as occurring in the spoil banks of coal-pits, where quantities of aluminous shales, with refuse coal containing iron pyrites, are heaped up together and exposed to the influence of the weather. The oxidation of the iron pyrites results in sulphate of iron, and the sulphuric acid so formed—reacting on the alumina, potash, etc., of the shales—forms a more or less complex alum, which may be observed in small stellate crystals between the laminæ of the shales. Alum slates and earths are very common, and all owe their origin to the oxidation of iron pyrites, or some other sulphide, under circumstances akin the above.

* The amount of oxygen in the atmosphere is about two trillions of pounds (Bischof, *op. cit.*, i., 204), equal to about 892,857,000,000,000 tons.

ORES AND METALLIFEROUS DEPOSITS.

The peroxides of iron and manganese are of considerable importance, both commercially and from a scientific point of view. In many cases the formation may be traced directly to the action of atmospheric oxygen. In other instances this action is but veiled by a series of complications. Many valuable deposits of iron and manganese are formed in cavities of rocks through the means of water containing carbonic acid and oxygen. The first dissolves the minerals as bicarbonates ; then, the excess of carbonic acid escaping as opportunity permits in open fissures, they are oxidized, and deposited at once in an insoluble form, while such other carbonates as happen to be in solution, and which—like lime, magnesia, and the alkalies—have a stronger affinity for carbonic acid than for oxygen, are carried away.

By such a process as this, immense beds of limonite have been deposited, and the liberated carbonic acid restored to the atmosphere. Bog iron-ores and the well-known lake iron-ore deposits of Sweden, are cases in point. Some of these deposits are assisted by organic agency, some of the Diatomaceæ—*Gal-*

lionella in particular—being very active in this way ; but they are only accessory aids, the real work being due to chemical reactions between carbonic acid, oxygen, and soils or rocks. The extensive beds of hematite associated with the Antrim basalts, are unquestionably lake-deposits, as Prof. Hull has suggested, and must be due also to the reciprocal chemical action of the carbonic acid and oxygen from the atmosphere. These beds are now intercalated between the sheets of basalt, and sometimes reach a considerable thickness, consisting of beds of rich ore, poorer ore, and "lithomarge," which is a highly ferruginous clay. Prof. Hull considers that all these were deposited in a large lake or series of lakes. Assuming this, the *modus operandi* was probably this : The highly ferruginous basalt forming the shores of these lakes being subject to the action of atmospheric water, the iron existing as proto-silicate in the augitic rock, was dissolved out as carbonate and carried into the lake. The excess of carbonic acid then escaping, oxidation ensued, as in the case already referred to, and the iron was precipitated as a hydrated peroxide. At the same time fine sedimentary aluminous matter was also carried down and deposited, and, according as the amount of this was greater or less, a bed of lithomarge or workable ore was laid down. A fresh volcanic outburst eventually taking place, the lakes were covered in, and the ore bed preserved from denudation.

The ore must have been precipitated in the hydrated state, and the water of combination was doubtless afterwards given off spontaneously, in the same way as by hydrate of alumina and the hydrated forms of silica. There is indeed considerable analogy between the hematites and the colloid forms of quartz. It is only necessary to compare these pisolitic and botryoidal iron-ores with the calcedonys to see this, and the comparison would be in favor of the aqueous origin of such iron-ores were fresh proof needed.

It will be obvious that the reactions sketched out above with regard to iron-ores and compounds, applies equally to all other minerals capable of being oxidized or reduced. Copper pyrites, for instance, is often oxidized to sulphate, and the carbonate altered to oxide just in the same manner.

ANTAGONISTIC ACTION OF CARBONIC ACID AND OXYGEN.

Clearly, then, the carbon and oxygen derived from the atmosphere sustain antagonistic parts in their action on rocks and minerals. They are perpetually warring the one against the other, and thus keeping a circulation between the earth and the air. The carbon reduces the oxides whenever it encounters them, and the oxygen replaces the carbonic acid of carbonates with the same inveteracy. The combined effects of these elements in geological transformations is extraordinary when we come to reflect on it. Regarded from an utilitarian point of view, to them we owe probably every metalliferous deposit of value in the world. I have shown how a highly ferruginous rock, such as basalt, containing proto-salts of iron, which are soluble in carbonic acid, might be acted on directly by that acid from the atmosphere. But there are cases where insoluble compounds of iron in small quantity, locked up in rocks, are, by the reducing action of the carbon of decaying vegetation, liberated, and finally accumulated in such quantities as to be of commercial value. Soils and clays contain small portions of per-oxide of iron, which is insoluble. The decay of vegetation or other organic matter robs this of oxygen, giving rise to carbonic acid. The resulting *protoxide* is soluble in water containing carbonic acid, or other organic acids, and is carried down into lakes or fissures, where, again absorbing oxygen, it forms beds or veins of hematite.

While insoluble oxides are rendered soluble and allowed to accumulate in this way, soluble sulphates are reduced to insoluble sulphides,—iron pyrites, copper pyrites, zinc blende, galena, &c.,—and, as Sterry Hunt puts it, "removed from the terrestrial circulation," for a time at least. Such are the processes to which many metalliferous deposits are due.

Another result of the opposition of these two atmospheric gases is the defertilizing of soils, and consequent failure of vegetation. An ordinary fertile natural soil contains, amongst other things, silicates of alumina, lime, potash, and

soda, with some peroxide of iron. The silicates of lime and soda will be decomposed by carbonic acid, and the bases removed as corbonates. The potash silicate is also decomposed, and a part of the potash removed by aquatic plants under favorable circumstances, in marshy places, &c.,—conditions under which the vegetation of the Coal era flourished,—and the ferric oxide is reduced to the ferrous state by the deoxidizing influence of rotting vegetation. This having occurred, the roots of plants are for a time debarred from any access of oxygen, for any that permeates the soil will be immediately siezed on by as much of the proto-compound of iron as has not been carried off in its soluble state, and this is again converted to the higher condition; and these changes continue until they result in the total barrenness of the soil and its ultimate conversion into a hydrous silicate of alumina, almost entirely free from iron, such as we are acquainted with in the fire-clays of the coal-measures—those ancient soils on which the vegetation now forming our coal-seams once grew.*

AMMONIA AND ITS COMPOUNDS.

Ammonia exists in the air chiefly in the form of carbonate of ammonia, but the quantity, whilst always small, appears to vary greatly, and it is not positively ascertained whether the variation is to be ascribed to natural causes, or ought to be referred to the difficulty of accurate analysis when such small quantities have to be dealt with. It is quite possible, however, that the variability is natural. The minimum recorded is 0.1 part of carbonate of ammonium in one million of air; the maximum is 135 parts.† Rain-water, hail, snow, and dew contain appreciable quantities of ammoniacal salts, and in rain from thunder-showers the ammonia is combined as nitrate, the effect of the electric discharge being to oxidize a portion of the nitrogen of the air to to nitric acid.‡

The atmospheric ammonia is not without its effect on vegetation. It is certain that plants grown in air perfectly free from ammonia never flourish to the same extent as those surrounded by an atmosphere containing some of it; and the experiments of Boussingault, Lawes and Gilbert—borne out as they are by those of Stockhart, Peters and Sachs, and lately by the very conclusive researches of Shlœsing* and A. Mayer†—show that at least a considerable part of, if not all, the nitrogen of plants is derived from this source. Now the geological connection of this is at once plain, for the decomposition of nitrogenous matter such as plants, in rocks, may lead partly to the formation of nitrates, or, by the evolution of nitrogen and ammonia in volcanic regions, give rise to other minerals, as I shall show presently.

Occasionally the ammonia is absorbed directly from the air by surface mineral matter, as in the case of the volcanic earth of the Solfatara of Puzzuoli. S. de Luca‡ tells us that this contains a quantity of sulphur and arsenic which under the influence of air and moisture form acids, and at once, combine with the atmospheric ammonia. But it is to the decay of vegetation that the vast majority of the nitrogen compounds which are met with, either as minerals or as volcanic emanations, are due, and in whatsver state the nitrogen was originally absorbed—whether in the free state or as ammonia—it cannot be doubted that all the nitrogen compounds contained in the earth, as it now exists, are traceable entirely to past and present atmospheres.

The nitrogenous compounds so obtained are themselves subject to an endless variety of changes, in which the gases already described bear no unimportant parts—reducing and oxidizing; and these changes, or the effect of heat, may result in a renewed evolution of ammonia to the atmosphere.

Under such circumstances occasionally the ammonia, instead of escaping freely

* It is obvious that this only applies to natural soils, since the agriculturist by breaking up the ground affords a supply of oxygen much in excess of what is absorbed by the oxidizable matter present.

† Watts, Chem. Dict., p. 439. P. Truchot finds that the amount of ammonia varies with the altitude. At Clermont-Ferrand, 395 metres above sea-level, the quantities were 0.93 m.grm. to 2.79 m.grms. in a cubic metre of air,—according as the day was clear or dull,—whilst at Pic de Sancy, 1884 metres, it amounted to 5.27 and 5.55 m.grms. under the same conditions. Comptes Rendus, lxxvii., 1159—1161.

‡ Liebig found that of seventy-seven specimens of rain-water, seventeen, collected during thunder-storms, contained nitric acid combined with lime and ammonia. Of the remaining sixty but two contained traces of it.—Bischof, *op. cit.*, i., p. 214. According to Bottger, the induction spark passed through moist air gives nitrogen peroxide and ozone, but in dry air gives nitrous fumes.—*Chem. Centr.* (1873), 497. Doubtless similar results follow discharges of natural electricity.

* Comptes Rendus, lxxviii., 1700.

† Deut. Chem. Ges. Ber., vi., 1404—1413, and Landw. Versuchs. Stat., xvii., 329.

‡ Comptes Rendus, lxxx., 674.

into the air, meets with hydrochloric as in the depth of volcanoes, and combining with it is evolved as chloride of ammonium (*sal-ammoniac*), which is condensed on meeting with the cooler external air. This mineral is often met with in large quantity, so much so, indeed, as to be of commercial value. Thus during the eruption of Vesuvius in 1794 great quantities of this salt were evolved, and it was collected by the peasantry; and Hecla in 1845 yielded very profitable supplies of it. In the vapours of the Solfatara, at Puzzuoli, it is also met with, and it is found mixed with sulphur and other matters in the crater of Vulcano, where it is now being largely collected,* and in considerable quantity at Etna. Then the volcanoes of Kutsché and Turfan, in Central Asia, afford such large supplies that it has been a very valuable article of commerce.†

Prof. Judd is at loss to explain the production of those large quantities of sal-ammoniac, unless on Daubeny's supposition that nitrogen under the influence of heat is unusually active; but the matter is readily accounted for thus:—The decomposition of nitrogenous organic matter at all times produces ammonia, but especially so under the influence of heat (a familiar instance in the manufacture of coal-gas). That a sufficiency of such organic matter exists in the rocks through which these volcanoes have burst is undoubted, and the ammonia evolved combines with avidity with the hydrochloric acid‡ also given out in volcanic emanations.

Quite lately a new mineral has been discovered incrusting the recent lava both of Etna and Vesuvius. This is a nitride of iron named "*Siderazote*" by its discoverer, Silvestri,‖ who considers it is due to the decomposition of ammonium chloride by heat in the presence of ferruginous lavas; and although we may not quite accept his theory that the ammonium chloride is formed by the absorption of nitrogen direct from the atmosphere by the lava, it is certain that the nitrogen has been originally drawn from that source. We may fitly conclude this part of the subject with the mention of the native sulphate of ammonium *Mascagnine*, of which it may be said that every constituent could have been obtained from the atmosphere.

NITROGEN.

It is obvious that much of what has been said regarding ammonia will apply to nitrogen, but on the whole the latter in its free state appears to have but little influence as a geological agent.

SULPHURIC AND SULPHUROUS ACIDS.

The exceedingly minute traces of these acids make but a slight effect on rocks when compared with the gases already touched upon. That they are not altogether inert may be taken for granted, but both their absorption and re-evolution are of a local nature, being chiefly apparent in the neighborhood of large towns and about volcanic regions. They may be "withdrawn from circulation" as sulphates and sulphides, and be returned in their original state, or decomposed into sulphur or sulphuretted hydrogen.

VARIATIONS OF ATMOSPHERIC PRESSURE.

These cannot but have an appreciable effect on certain classes of geological phenomena. The emanations of gases from the interior of the earth are influenced in some degree. It is well known that explosions in coal-mines sometimes follow a sudden fall of the barometer, which can be well understood on comparing the pressure corresponding to different barometric heights.

Barometer at 28 inches.		Atmospheric pressure		13,70	lbs.
"	29 "	"	"	14,19	"
"	30 "	"	"	14,68	"
"	31 "	"	"	15,17	"

It is usual to refer to the atmospheric pressure as about fifteen pounds on the square inch, but the above table shows that a considerable variation makes itself felt within the barometrical range. This must not only control evolution of gases from coal-seams, but also exhalations from open grottoes and caves, mineral springs both thermal and otherwise, and probably from intermittent active volcanoes, such as Stromboli, where the periodical explosion of gases is an important

* J. W. Judd, "On Volcanoes," Geol. Mag., Dec. 2, vol. ii., p. 113.

† Bischof, *op. cit.*, i., 212—213.

‡ The formation of white fumes of ammonium chloride when a glass rod dipped in ammonia is brought near hydrochloric acid will occur to chemical readers.

‖ "The Occurrence of Nitride of Iron amongst the Fumarole Products of Etna, and its Artificial Preparation." Orazio Silvestri, Gazetta, Chim. Ital., v., 301—307. Pogg. Ann., clviii., 165—172.

phenomenon. With regard to this Mr. Judd says "that the barometrical condition of the atmosphere must exercise a powerful influence on such a series of operations as are seen to be going on within the crater of Stromboli, few, probably, would be bold enough to deny." It appears "that the more violent states of activity . . . . coincide with the winter seasons and stormy weather, and its periods of comparative repose occur during the calms of summer, is established not only by the universal testimony of the inhabitants, but . . . . by the actual observations of many competent authorities." It is hardly necessary to point out that during stormy and wintry weather the barometer is mostly low, while the contrary is the case during summer time and calms.

It is not impossible that similar antagonism between outward and inward pressure may affect the working of many other vents, such as the Solfatara of Naples, and mud-volcanoes, such as those of Sicily, Transylvania, &c.; and that such variations may have no inconsiderable results, both as regards the chemical and cosmical effects of volcanic action.

And now, reviewing the preceding notes, it will be seen what an all-powerful geological agent the atmosphere we breathe is. Without its aid we should know never a stratified formation. The earth would simply form a ball of truly primitive rock, resulting from the cooling down of the original nebulous mass set apart for our globe, the only variation in which primeval and perennial crust being that of the different strata of higher specific gravity towards the interior. We should have no coal, no metalliferous deposits, no rivers or seas, and no rain,—consequently no denudation by "Rain and Rivers,"—for the vapor of water could not ascend into empty space. We should have——but, last and worst of all, there would be no "we." Life would be impossible, and the earth would finally degenerate into a

——"pale-faced moon."

That this is probably her ultimate mission cannot be denied. The only consolation is that owing to her larger size, and therefore slower rate of cooling than the moon, she will have gone through a somewhat more extended geological course. There is undoubtedly a very intimate connection between secular cooling and withdrawal of atmosphere, for the cooler the interior the smaller will be the return of gaseous elements to the surfaces; and probably before Saturn and Jupiter have cooled down to a habitable temperature, the senescent earth will roll through space—cold, void and airless. Sooner or later nothing is more certain than that

——"to this favor she must come."

MAXIMUM STRESSES IN FRAMED BRIDGES.

By Prof. WM. CAIN, A.M., C.E.

Contributed to Van Nostrand's Magazine.

II.

51. The weights just found are in excess of average practice. This is partly because we assumed an engine weighing 84000 lbs. on drivers in space of twelve feet, the total weight of engine and tender, covering fifty feet, being taken at 160000 lbs., whereas a common specification gives the live load as 60000 lbs. on twelve feet, the engine and tender weighing 130000 lbs. The car loads ordinarily assumed are from 2000 to 2240 lbs. per foot. We have also used smaller unit strains than usual for some bridge members. Since the Ashtabula accident it was proposed to the Ohio Legislature to assume for bridge computations a live load of two locomotives and tenders, the locomotives weighing 91200 lbs. on $12\frac{1}{2}$ wheel base, followed by cars weighing 2250 lbs. per foot of track.

In the Keystone Bridge Company's "Album" p. 22, we read; "For main lines of traffic, it is not considered prudent to assume less than 40 tons in a span of twelve feet,—stringers spanning over 12 feet should be sufficiently strong

to carry $1\frac{1}{2}$ tons per foot for each additional foot." (The 2000 lbs. ton is meant.) Considering the fact that engines are built with us weiging 100000 lbs. on 19 feet, it would seem that, for roads that use such engines, the live load assumed, art. 14, is certainly not too great. For secondary lines a less weight might be assumed, if the road is to continue secondary.

Mr. C. Graham Smith, in a paper read before the Liverpool Enginering Society, of which he was President, June 20, 1877, and republished in the "Engineering News," Chicago, says:

"Mr. Benjamin Baker has conclusively proved, in his admirable little work on 'Long Span Railway Bridges' that there are many circumstances, such as badly maintained permanent way, inclined cylinders, and unbalanced portions of the mechanism of locomotives, together with great weight and length of engines, combined with short wheel base, which will at times render the effective load on one axle equivalent to thirty tons . . . .

"With shallow cross girders, oscillations are set up by heavy continuous traffic which will soon shake loose rivets and bolts and perhaps the connections with the main girders . . . .

"Here is an actual example, recorded in the before mentioned 'Long Span Railway Bridges.' The platform of the railway bridge over the Regent's Canal was constructed, owing to local circumstances, with cross girders only 8 inches deep and 14 feet 6 inches span. With a view of compensating as much as possible for want of depth, longitudinal stiffening girders 18 inches deep were placed at a distance of 2 feet 3 inches from the outer edge of each rail; each cross girder was also well secured by tee iron and gusset plates to the main girders. The bridge, notwithstanding that with 15 tons to one axle, it was so designed that the iron should not be strained more than 4 tons per square inch, completely gave away in four years. Mr. Baker attributes the failure to the employment of a 45 ton engine, the wheel base of which was 14 feet; the ends consequently overhung very much, which would greatly assist in producing oscillations and other undesirable consequences."

Similar facts have been recorded in this country, though the use of trucks causes our locomotives to run much steadier than English ones. The use of deep girders is then advisable, and 50 per cent. may be added to the live load of stringers as an additional precaution. Experience, too often costly at that, can alone decide the effect of the impact, &c., caused by a live load. Its effect is usually included by adding some per cent. of the live load to the total load regarded as static.

52. The weight of chords, in table above, is greater than usual perhaps, as it is not generally customary to find the maximum strain in the chords as above. If two opposing trains meet in the center of the span or elsewhere on the span, the strains induced would be greater than given by our formulæ if the center driving wheels of the two locomotives are less than 50 feet distant. The conditions, included in the formula for chords, are that cars may precede and follow engines 50 feet apart, a condition that certainly can be realized in practice. In fact the end panels would be strained nearly as given by our formula, with engines in front as usual.

The maximum chord strains thus found will however be more rarely felt than the max. web strains, for the latter are caused by every passage of the supposed train—engines in front—whilst the former are only felt when the engines are in the midst of a train. Let us conceive the whole live load *uniformly* distributed over the bridge; the total panel weight then would be 35666 lbs., which substitute for P in the formula, art. 39, and make $E=o$. We have,

$$c_n = t_n = \frac{Pl}{2h}(N-n)\ n = 10600\ (N-n)n$$

On computing the various chord strains from this formula and comparing with the *max.* strains previously found, we shall find that we must add 10 per cent. to strains in first two end panels, 9 per cent. for next two panels and 8 and 7 per cent. to the strains in panels next the center, in order that the strains thus found may equal the max. strains.

For the simple trusses just examined, the determination of max. chord strains is simple, but for compound trusses with two or more systems of triangulation, the method is tedious comparatively, and in practice it would be best to ascertain and tabulate for various spans and loads, the percentages to add to the strains resulting from the load regarded as uniformly distributed.

53. *Permissible Strains per Square Inch in Tension and Compression.*—In Van Nostrand's Magazine for Nov. 1877, p. 459, is an article by the writer on this subject. A brief summary of it will be given.

Weyrauch (see "Constructions of Iron and Steel," Chap. XIII) deduces from

Wohler's experiments, by Launhardt's formula, the following value for the safe strain in kilograms per square centimeter $=b'$ to which wrought iron should be subjected in tension.

$$b'=\frac{2100}{n}(1+\tfrac{1}{2}\theta)$$

where n=factor of safety, $\theta=\frac{\text{min. B}}{\text{max. B}}=$ $\frac{\text{minimum strain that piece ever bears}}{\text{maximum strain that piece ever bears}}$

Impact, vibration, &c., such as a live load causes is not included; and I assumed that its effect varied inversely with θ, and wrote empirically, for *the safe strain on wrought iron ties in lbs. per square inch*,

$$b=7500\ (1+\theta) \quad . \quad . \quad (7)$$

Also, the *safe strain on wrought iron columns in lbs. per square inch*,

$$b=\frac{1}{4+\frac{1}{10}\left(\frac{l}{d}\right)}\ \frac{38500}{1+c\left(\frac{l}{r}\right)^2}(1+\theta) \quad . \quad (8)$$

where $c=\frac{1}{36000}$ for pillars with *flat ends*, $c=\frac{2}{36000}$ for *both ends hinged*, and $c=\frac{1}{24000}$ for *one end flat, the other hinged*; l=length of pillar in inches; d=diameter in direction of bending in inches, and r=radius of gyration of cross section about neutral axis in inches. The factor, $\frac{38500}{1+c\left(\frac{l}{r}\right)^2}$, is supposed to be the crippling weight of the column. This term is found *not* to be constant for different forms of cross section as "square column," "Phoenix," "American" or "common" column.* It would be proper then to replace 38500 and the values given above or found experimentally for c, by the corresponding terms for the particular cross section as found from experiment.

54. The above formulæ cause b to diminish for web members more rapidly towards the center of the span than Weyrauch's formulæ do. As impact is more hurtful the smaller the member and as the weight of web members diminishes towards the center of the span this appears reasonable. Should we assume that b from impact alone varied with the weight of the web member of a bridge, the result would be somewhat different from the above, since the weight of web members increases pretty regularly from the center to the abutments, whereas θ increases most rapidly at first.

55. For the chords it will be sufficiently near to put

$$\theta=\frac{\text{dead load of bridge}}{\text{total dead and live load}}$$

Thus in the example art. 42 for chords

$$\theta=\frac{336000}{336000+520000}=\frac{336}{856}=.39$$

If the chord strains are determined by supposing the bridge *uniformly loaded*, then θ is correctly determined as above.

56. Since the strain on any web member is equal to the shearing force on that member multiplied by sec. i,

$$\theta=\frac{(\text{min. S})\ \text{sec.}\ i}{(\text{max. S})\ \text{sec.}\ i}=\frac{\text{min. S}}{\text{max. S'}}$$

for web members.

Then, arts. 26 and 27, and table art. 21 we get

Panel	Shearing Forces		θ
	Max.	Min.	
1	216108	77000	.36
2	181840	59112	.32
3	148960	39836	.27
4	117468	19172	.16
5	87364	— 5380	0
6	58648	—31320	0

As given in the table art. 42.

If the strains on the web members are known, they may be used in place of the corresponding shearing forces, if preferred.

57. We see that for a 200′ span bridge weighing 336000 lbs., that b, for tension, is varied from 7500 lbs. per square inch on counters and middle ties to 10420 lbs. per square inch for lower chords. Extending the formulæ now to other spans, we should similarly find that for spans of 0, 100, 200, 300, 400 feet, b would vary from 7500 lbs. at center on web ties to 7500, 9400, 10400, 11300, 12200 respectively on end ties or lower chords. When $\frac{l}{d}=10$, nearly the same figures

* See *Engineering News* (Chicago), January 31, 1878, for proposed constants in Gordon's formula.

apply to posts. Thus eqs. (7) and (8) give nearly the same value for all values of θ when $\frac{l}{d}=10$.

58. When the engine comes directly on a member, the effect of impact is much greater than for the web members and must be allowed for empirically; thus we have added 50 per cent. to stringers and floor beam loops, the latter because of their small size.

For the floor beams we have supposed M in B$=o$ $\therefore$ $\theta=o$ and $b=7500$.

For wind strains values of b of 1500 for ties and 5000 for struts was used as the conditions assumed are so rarely fulfilled. It may be remarked that nothing has been added to the chords for wind strains, though its effect must be severe on them, causing *inequality* of strain—another reason why the chords should be computed for maximum strains as in art. 40.

59. The above formulæ (7) and (8) may or may not bear the crucial test of practice. It will probably be admitted however that they possess great advantages in properly comparing different forms of trusses of the same span, to which use they will be put in what follows. Empirical rules in ordinary use are wanting in this; they do not recognize Wohler's law—that the minimum strain sufficient for rupture *decreases* as the difference between the extremes of strain to which the piece is liable, *increases.*

The deduction of Launhardt from Wohler's experiments, that b varies with θ is included in the formulæ above; and the coefficient of θ was changed from $\frac{1}{2}$ as given by Weyrauch to 1 to allow empirically for impact.

60. Gerber also deduced formulæ from Wohler's experiments including 50 per cent. added to live load for impact. Formula (7) above agrees very closely with the values *used* in the Mainz bridge by Gerber, though for $\theta=\frac{2}{3}$ to 1 his formula gives much larger values than eq. 7.

When $\theta=1$, impact is supposed null and $b=15000$ lbs. This seems sufficiently large, though Gerber gives in his Mainz bridge and later formulæ, 22760 lbs. per square inch.

61. The variable factor of safety for posts, $\dfrac{1}{4+\frac{1}{10}\frac{l}{d}}$ is used to give values for a 200 feet span in accordance with the recommendations and usage of American engineers.

No formulæ for wood is given, as no experiments have been made after Wohler's manner upon it.

62. The compression members in the table art. 42 were supposed hollow cylindrical and of wrought iron. Therefore in eq. (8), $r=\frac{d}{4}\sqrt{2}$. The end upper chord panels were regarded as "flat at one end, hinged at the other;" the other panel lengths as "flat at both ends." The braces were regarded as "hinged at both ends."

The panel length assumed may not be the most economical. It is only by computing the whole weight of the bridge for different panel lengths that the proper panel length can be determined. The most economical height of truss will be considered later.

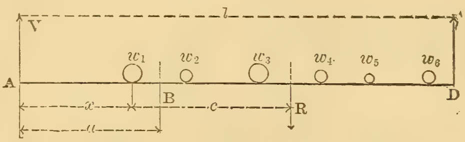
63. The following table of "crippling weights" may prove a convenience:

(*See Table on following page.*)

64. *Maximum Chord Strains due to any number of equal or unequal weights placed at fixed distances apart.*

Let w_1, w_2 . . . . at fixed distances apart be placed on the girder AD, of span l. Let $R=w_1+w_2+m=\Sigma w$, be the resultant of w_1, w_2 . . . in position and magnitude.

FIG. 8*a*.



Call x the distance from A to w_1, C= distance from w_1 to R, a=distance from A to the cross section *whose max. moment, as the load moves forward, is required.* We have $Vl=R(l-x-c)$.

1/. *When w_1 and w_2 are on either side of* B, the moment at B is

$$M=Va-w_1\,(a-x)=\left\{R\left(1-\frac{c}{l}\right)-w_1\right\}a+\left(w_1-R\right)x \quad . \quad . \quad . \quad . \quad . \quad (9)$$

HOLLOW CYLINDRICAL COLUMNS.

$\frac{l}{d}$	Flat Ends. $\dfrac{38500}{1+\frac{2}{9000}\frac{l^2}{d^2}}$	One end hinged. $\dfrac{38500}{1+\frac{1}{3000}\frac{l^2}{d^2}}$	Both ends hinged. $\dfrac{38500}{1+\frac{4}{9000}\frac{l^2}{d^2}}$	$4+\frac{1}{10}\frac{l}{d}$
10	37663	37258	36862	5.
11	37492	37008	36535	5.1
12	37306	36736	36184	5.2
13	37106	36447	35810	5.3
14	36893	36139	35414	5.4
15	36667	35814	35000	5.5
16	36428	35473	34567	5.6
17	36177	35117	34117	5.7
18	35914	34747	33653	5.8
19	35640	34365	33177	5.9
20	35357	33971	32688	6.
21	35064	33566	32190	6 1
22	34761	33152	31684	6.2
23	34450	32729	31171	6 3
24	34131	32298	30653	6.4
25	33805	31862	30130	6.5
26	33472	31420	29605	6.6
27	33133	30973	29079	6.7
28	32787	30523	28551	6.8
29	32438	30070	28025	6.9
30	32083	29615	27500	7.
31	31725	29159	26977	7.1
32	31363	28702	26458	7.2
33	30998	28246	25943	7.3
34	30631	27791	25433	7.4
35	30262	27337	24928	7.5
36	29891	26885	24428	7.6
37	29520	26436	23936	7.7
38	29147	25990	23450	7.8
39	28774	25547	22971	7.9
40	28402	25109	22500	8.

When $\left(w_1-R\frac{a}{l}\right)>o$, M increases with x; *i.e.*, M is a max. for $x=a$. (We must not consider $x\times a$, since V and hence M would be diminished). If $\left(w_1-R\frac{a}{l}\right)>o$, M increases as x decreases, which moves w_2 up to B at last. When the coefficient of x is zero, w_1 or w_2 may be supposed at B, or B must lie between them.

2/. *But* M *may be a max. when* w_2 *is to the left of* B. In this case regard $w_1+w_2=P$ as a a single force.

Call c_1=distance from the center of gravity of w_1 and w_2 to R, *i.e.*, from P to R,

and x=distance from A to P.

Then the above equations hold, on simply substituting P for w_1.

As before, when $\left(P-R\frac{a}{l}\right)>o$, M increases with x and is a max. when w_2 is over B, but it must not be supposed to the right of it, as the equation does not now include this supposition. This position of the load then gives M a *max*.

3/. If, however, $\left(P-R\frac{a}{l}\right)<o$, M increases as x decreases, whence the load is moved forward so that w_3 rests upon B.

Next, calling $w_1+w_2+w_3=P_1$, c_2= distance from P_1 the resultant of w_1, w_2, w_3 in position and magnitude to R, and x= distance from A to P; eq. (9) holds as before on substituting P_1 for w_1. We proceed as before to ascertain if M is a maximum when B is between w_3 and w_4 and so on for other positions of the loads.

65. As w_1, w_2 . . . pass off the span, they must no longer be included in the formulae for R, c, M, etc. For a framed truss, a is the distance from A to the apex that is taken as the center of moments for the opposite chord panel. As it is only necessary to consider half a truss, the maximum strains in the chords being the same for the other half when the load moves in an opposite direction, *we must not take* $a>\frac{1}{2}l$.

66. *Example.* Consider the three trusses, Figs. 5, 6 and 7, to be of 400 feet span, each with 20 panels, the panel lengths thus being 20 feet each. Let five equal weights w (as the locomotive excesses, art. 16, 38) be placed on the span at equal or unequal distances apart. Then $R=5w$ and in eq. (9), $\left(w_1-R\frac{a}{l}\right)$ $=w\left(1-\frac{5a}{l}\right)$, which is positive when $a<\frac{l}{4}=80$ feet; hence art. 64, 1, to find the maximum chord strain on the first four panels from the abutment, the loads w, w . . . must extend from the center of moments for the panel considered (art. 65) towards the center. For the fifth chord panel $\left(1-\frac{5a}{l}\right)$ is negative, so that the second weight moves up, at least, as far as its center of moments; then proceeding as in art. 64, 2; $P=2w$, and $\left(P-R\frac{a}{l}\right)=w\left(2-\frac{5a}{l}\right)$ is +, so long as $a<\frac{2}{5}l=160$ feet. So that for panels 5, 6, 7, 8 (and 4 if preferred), the second

weight must be supposed up to the panel considered, to ascertain its maximum chord strain.

Finally, $\left(2-\frac{5a}{l}\right)<o$ for $a>160$, or 8 panel lengths. Therefore in art. 64, 3, put $P_1=3w \therefore \left(P_1-R\frac{a}{l}\right)=w\left(3-\frac{5a}{l}\right)$ is $+$ when $a<\frac{3l}{5}=240$ feet.

Hence for panels 9, 10, (and 8 if desired) the middle weight is placed at their center of moments.

The above results are independent of the distances apart or magnitude of the equal weights. It is seen that the maximum moment for an end panel is when the front weight reaches to it; whilst the max. moment at the center is when the middle weight is at the center, and for intermediate panels the loads have intermediate positions. It will be instructive for the reader to test the above results, by assuming various positions of the loads for each panel in turn.

When the loads are unequal the application is equally simple and direct.

67. Referring to eq. (9), and regarding w_1 as the resultant of all the weights to the left of B, we see (as was remarked in art. 64) that *when* a has such a value that,

$$w_1-R\frac{a}{l}=o \therefore w_1l-(w_1+w_2+\ .\ .\ .\ )a=o$$

$$\therefore \frac{w_1}{w_2+w_3+\ .\ .\ .\ .} = \frac{a}{l-a},$$

that the greatest moment ever experienced at B obtains; and we see from the last eq. that this occurs when *the loads on either side of B are in the ratio of the segments into which it divides the span.* This conclusion is reached in DuBois, Graphical Statics, art. 73. Though this author seems to regard the analytical treatment of a given recurring system of moving loads as almost impracticable, (see his Preface, p. xi.)

It is believed that the above solution is practical and simple; in fact, much more so than the one by the graphical analysis.

COMPOUND SYSTEM.

68. As the span increases, the panel lengths become too long for economy, or the inclination of the web diagonals, for usual panel lengths, is not the best for economy, for the trusses previously figured. Hence the use of compound systems such as the whipple, fig. 9, the Trellis, the Post, or even bridges of "treble" &c. "intersections," where the ties cross three or more panels.

69. *Web Strains.*—In the truss fig. 9 of 200 feet span and 28 ft. high, divided into 12 panels, weights as before, let w, placed below the apices, denote the *panel dead load; p* placed above the apices, the *panel car load;* and E, the *locomotive excess*, being the two weights at d and h in the figures. It will be noticed that any weight as that at f can travel to either abutment only by one web system, as a B d D f H h J . . . . The weight at e must follow the other system, a B c C e . . . . The weights inked black thus travel towards either abutment only by the first system, the others by the second.

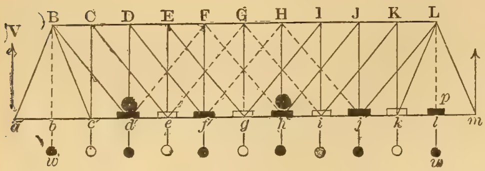
Now if the second engine is placed 50 back of the first, its position is g; but the interposition of a car $16\frac{2}{3}$ feet long, or different engine and tender lengths would locate it at h. As the object is to find the max. strain that can come upon each system in turn, we must place the second locomotive four panel lengths from the first, so that it will bear upon the same system as the first. This position may rarely happen, but it should be provided for in the sections of the web members, especially those near the center of the truss, such as the dotted "counters." The dotted lines $\overline{Bb}$ and $\overline{Ll}$ are "suspenders" like those in Fig. 7 and similarly strained to a max. of 46000 pounds.

70. The weight at l may be taken on either or both of the partial trusses into which we shall suppose Fig. 9 divided. As it only affects V, $\frac{1}{12}$ $(w+p)=2555$ pounds in this instance, it may act with a different system from that taken, without altering the sections an appreciable amount.

With vertical end posts there is no uncertainty, for then the weight at l can only act with the *black* system, as a tie extends from l to top of end post, the tie from k being also carried there.

71. If we cut the truss through between $\overline{cC}$ and $\overline{dD}$ as in Art. 7, and apply forces at the cut parts equal and opposed

FIG. 9.



to the resistances, the total shearing force, S, is, of course, V$-2w$; but S is the *sum* of the vertical components on the two cut ties, and without knowing the amount carried by one tie we are unable to estimate it on the other. Hence this general method must first be applied to one partial truss and then the other independently. First take the partial truss aBdDfFh . . . . , and call V the reaction at a due to the load on this truss. The reasoning of arts. 12 and 27 apply here in finding max. and min. S. Call Σw the *sum* of the *ws* between a and foremost locomotive on system taken; then having found V, when load, (engines in front) extends from farthest abutment we have

S$=$V$-\Sigma w$. Take moments about m,

Call l_1, the lever arm of E,

l_2, the lever arm of the resultant of the car loads p,

and m=the number of p's on the partial truss considered. Also let a panel length as $\overline{ab}$ be the unit of length. With the loads as in the figure $l_1=7$, $l_2=5$, $m=5$. We have as before, $w=14000$, $p=\frac{50000}{3}$ and E$=60000$.

$$V\,12=6\,w\,6+El_1+mpl_2$$

$$\therefore\ S=42000+5000.l_1+m.1390.l_2-\Sigma w.$$

In a similar manner we proceed for the other partial truss, finding the equation,

$$S=\tfrac{5}{2}\,w+\frac{E}{12}\,l_1+\frac{mp}{12}l_2-\Sigma w.$$

72. The results are entered in the following table. Note, from the figure, that as the live load moves two panels to the right, l_1 diminishes by 2, l_2 by 1, and m by 1. The table is thus very quickly formed. The max. shearing force on $\overline{a}$B$+216108$ lbs., found by supposing the whole bridge loaded as in art. 21. Thus

$$V=S=\tfrac{11}{12}(w+p)+9\tfrac{1}{2}\times\frac{E}{12}=216108.$$

PARTIAL TRUSS aBdDfF . . . .

Front Engine at	Piece.	$42000+5000.l_1+m.1390.l_2-\Sigma w=$	S.
d	Bd	$42000+5000.7+5.1390.5-0$	97750
f	dD, Df,	$42000+5000.5+4.1390.4-14000$	61240
h	fF, hF,	$42000+5000.3+3.1390.3-28000$	27510
j	hH, jH.	$42000+2500.3+2.1390.2-42000$	$-$ 940
l	—	$42000+2500.\ +\ 1390\ -56000$	-24110
		PARTIAL TRUSS aBcCeE. . . .	
		$35000+5000.l_1+m.1390l_2-\Sigma w$	
c	cB	$35000+5000.8+5.1390.6-0$	116700
e	Cc, Ce	$35000+5000.6+4.1390.5-14000$	78800
g	eE, gE	$35000+5000.4+3.1390.4-28000$	43680
i	gG, iG	$35000+5000.2+2.1390.3-42000$	11340
k	—	$35000+2500.2+\ 1390.2-56000$	-13220

73. Be careful to note when one locomotive leaves the bridge and modify the formula correspondingly. S sec. i gives the strain on the ties as before, sec. $i=\frac{43.5}{28}=1.553$ except for Bc; its value for that tie being $\frac{32.6}{28}=1.165$. The values of S above are the actual strains on the vertical posts opposite them. If those posts were inclined as in the "trellis" bridge (in which the posts $\overline{\mathrm{D}d}$, $\overline{\mathrm{F}f}$, &c., take the positions, $\overline{\mathrm{E}d}$, $\overline{\mathrm{G}f}$, &c.; the corresponding ties fD, hF, &c., the positions fE, hG, &c.; braces reaching from

C to b and from $\overline{\mathrm{K}}$ to l); we multiply S by sec. i to find the strains on them as well as the ties that are equally inclined. In the trellis, as in the triangular, some web members near the center take obverse and reverse strains.

74. It is implied in the previous computations that the reactions at the abutments of each partial truss are to be determined by the simple law of the lever *independently* of the other partial truss. *Unless the counter rods have little or no strain on them for a uniform load this assumption may be incorrect.*

To prove it: take the extreme case, that the main ties $\overline{\mathrm{B}c, \mathrm{C}e, \mathrm{E}g}$, are too long to be in action, and that counters, from c to E, $\overline{e\mathrm{G}}$, gI are *taut* (malicious or ignorant persons might screw up the counters so as to relieve the main ties above from strain), then the loads c, e and g must inevitably go to m. Now conceive panel cD severed. The total shear on this panel (art. 71) is,

$$\mathrm{V}-2w=\frac{11w}{2}+\frac{7\mathrm{E}}{12}+\frac{9p}{12}5-2w=146500=\mathrm{S}.$$

But since the shear w on the supposed rod $\overline{c\,\mathrm{E}}$ acts up, the actual shear on tie $\overline{b\,\mathrm{D}}$ is $\mathrm{S}+w=160500$ lbs.; *whereas we shall proportion it for* 97750 *lbs. shear as previously found?* Similarly for other panels. Practically, the counters are loose when the truss is first set up; the main ties are then necessarily in action; for even if a little long ($\frac{1}{64}$ inch say), the roadway sinks the apex and thus brings them into action (as the upper chord apex sinks too, the chord at this apex is thus unequally strained). Now, if the counters are tightened, *part* of the weight at c, e, . . . *will go* to m, from the law of decomposition of forces; and *the greater the initial strain on the counters, the larger the weight on the partial truss, a*BcCeE . . . *that is transferred to the right abutment.* The counters being of much lighter section than the main ties will stretch more and thus counteract this tendency, especially on the partial truss on which the locomotives bear.

95. As stated then, the partial trusses cannot act independently except when the counters are not strained for a uniform load. If they have a slight initial strain on them, the strains may be increased on the web members somewhat—an additional reason for supposing the second locomotive to bear upon the same system as the first, as we have done. It is then not only useless, but may be prejudicial to put counter rods, screwed taut, in panels where there is never any reversion of strain, as from c to E etc. With the loads assumed, S is—, (art. 73) for counters d F and j H, but a slightly greater load would bring them into action, hence they should be retained and their section assumed, say at 2 sq. in.

76. The preceding reasoning applies to all compound systems. In finding S for the simple systems, as figs. 5, 6, 7, no assumption was made as to the abutment to which any particular weight was transferred. But S is the total shear, and for figs. 5 and 6, if the counter carries any strain (as explained in art. 74) the shear on the main tie or brace is increased by that strain.

In the triangular truss, fig. 7, there is no uncertainty as to the strains; as the same piece, where necessary, takes tension and compression both.

77. It is recommended as good practice, where separate counter rods are used, "to put a *light* load on the bridge and then strap the counters down taut. They should not remain taut under full symmetrical loads, but should be tight enough to keep quiet under unsymmetrical loads; a medium that can be struck." "Practically the counter ties remain tight if adjusted intelligently and are not tampered with." Similar remarks apply to "keeping wooden counterbraces" recommended by Haupt. As any deflection of a truss is accompanied by an increased length of main ties, and a shortening of the counter diagonals, if the counters are strapped down when there is a light load on the bridge, for a full symmetrical load they will be loose; for a dead load only, they will be tight. This is as it should be.

(*Remark.* The whole of the rearmost loc. excess was supposed to bear at one apex only, thus giving slightly larger strains than the true ones, to *allow* somewhat for improperly adjusted counters.)

78. *Chord Strains.*—Suppose the truss loaded at each lower apex with $(w+p)=w'$ (the weights below the fig. can now be taken for w') and of the two weights

30,000 lbs. each, either 3 panels (50 ft.) apart, or a greater distance, if the chord strains are thereby increased.

As before, we assume that each partial truss acts independently of the other; find the strains on any chord piece as $\overline{CD}$, due to each partial truss and add them for the total strain on that member. If it is simpler, the reader may draw the two partial trusses separately to estimate the effect of each.

79. *The Locomotive Excess*, E=60,000 lbs., is made up of the two weights, 30,000 lbs. each. For convenience call the foremost P, the rearmost, P′.

Now the chords may receive their maximum strains when P and P′ act in the same system, 4 panels apart; or in different systems, 3 panels apart. The principles of art. 34 are of some assistance, but we can only determine by actual trial, for each chord panel in turn, the proper relative position of P and P′ that give the max. strains for that panel. Hence I have estimated the effect of P and P′ separately, and have taken those positions of P and P′, *either* 3 *or* 4 *panels apart*, that gave the greatest strains for each chord panel. The height of truss was taken as before at 28 ft. The results are as follow:

Piece.	P at	P′ at	Max. Strains.	P, 4 panels from P′.
			lbs.	lbs.
ac	*b*	*e*	28274	—
cd	*c*	*g*	47619	47619
de or BC	*d*	*h*	62500	62500
ef or CD	*d*	*g*	75893	71433
fg or DE	*e*	*h*	84821	74410
EF	*f*	*i*	87798	71433
FG	*f*	*i*	87798	71433

Thus for $\overline{cd}$, $\overline{de}$ and $\overline{BC}$, the weights are 4 panels apart, for the others 3. Note again, that for some panels P is adjacent, and for others a panel distance from, the panel considered. It will be noticed above that for panels near the centre the strains are considerably greater when P and P′ are 3 panels apart, than when they are 4 panels apart.

80. To illustrate the method of computation, call *a panel length*$=ab=1$; the height of the truss is then $28\div\frac{50}{3}=\frac{84}{50}$. With P at *c*, its reaction at *a* is $\frac{10}{12}$ P. If $\overline{de}$ is cut, rotation about C would occur. The moment about C is $\frac{10}{12}$ P. 2 $=50000$. Next suppose P at *d*, the reaction is $\frac{3}{4}$ P. If $\overline{de}$ is cut, D is the point of rotation, and the moment is thus $\frac{3}{4}$ P $3=67500$.

Now when P is at *c*, conceive P′ at *f*; its reaction is $\frac{7}{12}$ P; and with D as a center of moments for $\overline{de}$ cut the moment$=\frac{7}{12}$ P $3=52500$. (It is needless to consider P′ at *g*, in this case, as V is less, also the point of rotation, for $\overline{de}$ cut, being C, for the truss *g* E *e l*′ . . ., the lever arm is less too).

Next with P at *d*, let P′ be at *g* ∴ V$=\frac{1}{2}$ P. Then for $\overline{de}$ cut, the moment about C is $\frac{1}{2}$ P. $2=30000$.

Lastly with P at *d*, conceive P′ at *h* ∴ V$=\frac{5}{12}$ P. For $\overline{de}$ cut, D is the point of rotation for truss *h* F *f* D . . . ., hence the moment is $\frac{5}{12}$ P. $3=37500$.

Collect now the moments for the piece $\overline{de}$.

Piece.	P at	Moment	P′ at	Moment	Total.
de	*c*	50000	*f*	52500	102500
de	*d*	67500	*g*	30000	97500
de	*d*	67500	*h*	37500	105000

With P at *d* and P′ at *h*, the actual moment is greatest. Divide it (105000) by the height of truss $\frac{84}{50}$ and we get the strain in $\overline{de}=62500$ lbs.

81. We see how much simpler the treatment of the simple systems is than the compound; still, if we desire to know the "true inwardness" of the compound systems, extra work is unavoidable.

It may be urged that when P′ passes to the right of all the counters none of its weight can be transferred to *a*: true, but with the uniform load in addition on the bridge, the law of the lever holds for each partial truss, since counters are designed in those panels where loads have to be transferred to the farthest abutment and the *effect must be the same in the final summation whether the two engines and the uniform load are treated separately or conjointly.*

82. For the uniform load, $w'=w+p=14000+16666=30666$ per panel; as before we *assume* that the partial trusses act independently and afterwards combine their effects for the same chord panel.

Thus to find the strain on $\overline{BC}$ due to the black weights: $V=\frac{1}{2}6\,w'$, with d as a center of moments,

$$(\text{Strain on } \overline{BC})\times\overline{dD}=V\times\overline{ad}-w'\times\overline{bd}$$

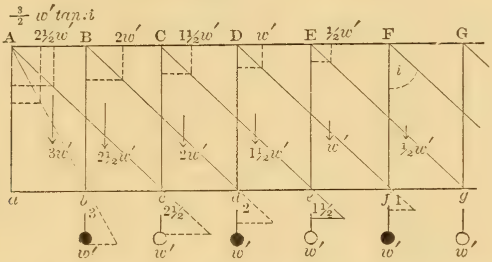
Similarly for the other partial truss, conceive $\overline{bc}$, $\overline{Bc}$ and $\overline{BC}$ cut and take the intersection of the first two, c, as a center of moments (art. 36). The reaction at a is $V'=\frac{5}{2}w'$

$$\therefore\ (\text{Str. on } \overline{BC})\times\overline{Cc}=V'\times\overline{ac}$$

The sum of the strains on $\overline{BC}$ thus found, added to that found for the locomotive excess, gives the total strain on $\overline{BC}$ which is evidently the same as that on $\overline{de}$.

83. The following is a more convenient method. The reaction at a due to the black weights is $3w'$; hence (art. 7), the *shears* on $\overline{bA}$, $\overline{dB}$, $\overline{fD}$ are $3w'$, $2w'$, w', respectively as is marked, on the half truss with vertical end-posts, Fig. 10. The shearing forces on the ties of the other partial truss are as marked on

FIG. 10.



them $2\frac{1}{2}w'$, $1\frac{1}{2}w'$, $\frac{1}{2}w'$. In fact $\frac{1}{2}$ of the w' at g (Fig. 9) goes to either abutment (if the counters do not act). At E the pull on the tie gE is decomposed into $\frac{1}{2}w'$ acting down the post Ee and $\frac{1}{2}w'$ tan. i, compressing EF, ($i=g$ Ee).

At e, the $\frac{1}{2}w'+w'(ate)$ acting vertically, is decomposed in the directions $\overline{Ce}$ and $\overline{ef}$, thus giving the strain on $ef=1\frac{1}{2}w$ tan. i. The shearing force on $\overline{Ce}$ is thus $1\frac{1}{2}w'$. Hence the pull on $\overline{Ce}$ at C gives $1\frac{1}{2}w'$tan. i, strain on CD, and $1\frac{1}{2}w'$ strain on post $\overline{Cc}$; and so on for all the weights, except that the pull on Ab, causes a strain on AB of $3\,w'$ tan. aAb $=\frac{3}{2}w'$ tan. i. Put aA$b=i_1$. The total strain on AB$=(\frac{3}{2}+2\frac{1}{2})w'$ tan. $i=3w'$tan. $i_1+2\frac{1}{2}w'$ tan. i.

Strain on BC=strain on AB$+2w'$ tan. i.
Strain on CD=strain on BC$+1\frac{1}{2}w'$ tan. i.
&c., &c.

Similarly,
strain in $\overline{bc}=3w'$ tan. $i_1=\frac{3}{2}w'$ tan. i.
strain in $\overline{cd}$=strain in $\overline{bc}+2\frac{1}{2}w'$tan.$i$, &c.
Hence the rule.

Multiply the shear on each inclined web piece by the tangent of its inclination to the vertical. The summation of these products from the abutment to any chord piece gives its total strains.

If the chord strain at center agrees with that found by moments the whole work is correct. This method can be applied to any truss.

83. Now by the principle of moments, the expressions for the strains in $\overline{BC}$, $\overline{CD}$ . . . , cd . . . are the same for Figs. 9 and 10. In fact the same method may be applied to Fig. 9, regarding the inclination, &c., at the ends, and the above rule deduced. The strains for the truss Fig. 9 are entered in the following table. By computation, we find, tan. $i=1.19$; tan. $i_1=.595$.

84. The total strain on $\overline{ac}$ Fig. 9 is the same as for Fig. 7, 128669 lbs. Since the shear on aB is $\frac{11}{2}w'$ we find the strain on ac due to uniform load $\frac{11}{2}w'$ tan. $i_1=100354$.

From table, art. 79, the max. strain due to E is 28274 which gives 128628 lbs. strain on $\overline{ac}$. The difference, 41 lbs., between this result and the former is due to carrying *tan. i* to two decimal places only.

Piece.		Increments.	Strains.
bc	$5\frac{1}{2}w'$ tan. i_1	100354	100354
cd	$2\frac{1}{2}w'$ tan. i_1	45616	145970
de or BC	$2\,w'$ tan. i	72984	218954
ef or CD	$1\frac{1}{2}w'$ tan. i	54738	273692
fg or DE	w' tan. i	36492	310184
EF or FG	$\frac{1}{2}w'$ tan. i	18246	328430

Taking moments about g we have

$$\text{Strain in } \overline{FG}=(\tfrac{11}{2}w.100-5w.50)\div 28$$
$$=328550 \text{ lbs.}$$

The slight difference between this result and that given in the table, shows the correctness of the work. The "increment" column can be "run up" from the bottom, adding $\frac{w'}{2}$ tan. i each time until we reach $\overline{cd}$.

85. Combining these results with those in art. 79 we enter them, also the web strains in the following table:

Piece.		d.	$\frac{l}{d}$	th	Strain.	θ.	b.	Area.	Length.	No.	k.	Weight.	Totals.
		″		″				□″	′			lbs.	
U. Chord,	BC	$13\frac{1}{3}$	15	$\frac{3}{4}$	281454	.39	9050	31.1	$\frac{100}{6}$	4	$\frac{10}{3}$	6911	
	CD	“	“	1	349585	“	9270	37.7	“	“	“	8378	
	DE	“	“	$1\frac{1}{6}$	395005	“	“	42.6	“	“	“	9467	
	EF	“	“	$1\frac{1}{4}$	416228	“	“	44.9	“	“	“	9978	
	FG	“	“	$1\frac{1}{4}$	416228	“	“	44.9	“	“	“	9978	44712
Posts,	aB	$13\frac{1}{16}$	30	$\frac{21}{16}$	251766	.36	5340	47.15	32.6	“	“	20495	
	Cc	10	34	$\frac{5}{8}$	78800	.17	4400	17.9	28	“	“	6683	
	Dd	“	“	$\frac{1}{2}$	61240	0	3750	16.3	“	“	“	6085	
	Ee	“	“	$\frac{1}{3}$	43680	0	“	11.62	“	“	“	4338	
	Ff	$8\frac{3}{8}$	40	$\frac{3}{8}$	27510	0	3140	8.76	“	“	“	3270	
	Gg	“	“	“	11340	0	—	8.76	“	2	“	1635	42506
Lower Chord					1476889	.39	10420	141.73	$\frac{100}{6}$	4	“	31496	31496
Suspender	Bb				46000	0	7500	6.13	28	“	“	2288	
Ties,	Bc				135955	.3	9750	13.94	32.6	“	“	6064	
	Bd				151806	.25	9370	16.2	43.5	“	“	9396	
	Ce				122376	.17	8780	14	“	“	“	8120	
	Df				95106	0	7500	12.7	“	“	“	7366	
	Eg				67835	0	7500	9.04	“	“	“	5243	
	Fh				42723	0	7500	5.7	“	“	“	3306	
	Gi				17611	0	7500	2.35	“	“	“	1363	
	Hj							2.	“	“	“	1160	44306

86. The value of θ for the chords is the same as in the previous truss examined, also for $\overline{a\text{B}}$ and $\overline{b\text{B}}$. From the table of shearing forces (art. 72), we find the following values for θ, according to the principles of arts. 26, 27:

Piece.	Maximum S.	Minimum S.	θ.
aB	216108	77000	.36
cB	116700	35000	.3
dB	97750	24110	.25
Cc, Ce	78800	13220	.17
Dd, Df	61240	940	0
Ee, Eg	73680	11340	0

The black weights were regarded as acting on the same partial truss. Min. S on $\overline{c\text{B}}$ is then due to dead load only, and is 35000 lbs.$=2\frac{1}{2}w$. Min. S on dB is the same as for $\overline{\text{L}j}$ when front engine is at l (art. 72). Similarly min. S on $\overline{\text{C}c}$, $\overline{\text{C}e}$ is the same as for $\overline{k\text{K}}$, $\overline{\text{K}i}$ when "front engine is at k." The dotted counters and hence the posts $\overline{\text{F}f}\ \overline{\text{G}g}$ sustain no strain from a uniform load. Hence for them $\theta=o$. It will be noticed that for the same panel θ, and hence b is less for the "compound" than for the "simple" systems. In the foregoing table the *posts* were regarded, as "hinged at one end."

87. The following is the

Bill of Materials.

Whipple Truss—200′ span—28′ high.

	lbs.
Posts..................................	42506
Upper chord...........................	44712
20 p. c. for castings, &c.........	17444
Ties, counters and suspenders. ..	44306
Lower chord............................	31496
15 p. c. on two last, for bolts, &c.	11370
Floor beam loops..................	5000
Lateral bracing.....................	11400
Floor beams (iron)................	24500
Iron stringers	60000
Rails, cross ties, &c.............	33200
Total weight of bridge.......	325934
Assumed weight......	336000
Assumed weight too great by....	10066

The weight of this whipple truss (325934) is thus 3915 lbs. less than the weight of the Triangular Truss (329849) allowing $\frac{1}{8}''$ as the least thickness of metal. If, however, as seems more proper, the vertical posts of the triangular truss that only sustain 2500 lbs. *dead* load, be given a thickness of $\frac{1}{6}$ inch, their section will be 4.5 square inch; and the weight of the triangular truss is reduced 4200 lbs. making it the lightest of the two. The weight of flooring, rails, loops, lateral bracing, etc., was assumed the same in both trusses. See art. 108 for a further comparison.

88. The Quadrangular Truss however, is more built than any other in this country, on account of its economy in first cost, the *square joints* being more easily and accurately machined than others; the posts too are vertical, thus ensuring less flexure under their own weight than inclined posts, and with certain details they can be made "flat at both ends," bearing against the upper chord and the upper flange of the floor beam.

It is evident from what precedes that "compound systems" require greater accuracy in filling than simple systems; and where counter rods are used, they should be properly tightened and often inspected, or grave consequences may ensue. It is evident, likewise, that the greater the number of systems used, the more care is required to make the actual strains agree with the computed; in other words, to cause each partial system to act independently of every other. The investigation of the maximum chord strains is more troublesome the greater the number of partial systems used. Many of the largest spans built or being built in this country, varying from 300 to 525 feet in length, are "double intersection," although treble and quadruple intersections are by no means unknown.

In latticed bridges where the diagonals are connected at their intersections. the strains are perfectly indeterminate, It would certainly then seem advisable to use those patterns of web in which the strains go where they are computed to go.

The weights computed above are, so far as I know, above average. Are they too great for a first-class road? The effects of high speed, with snow, great cold and side wind (for which no provision is made in the chords), ill fittings and perhaps some counters unadjusted should be considered conjointly with the statical loads in answering this question.

89. Let us now suppose the live load uniformerly distributed, and ascertain what percentages are necessary to add to the chord strains induced to equal the *maximum* chord strains (see art. 52).

The uniform live and dead load per panel is now $(168000+200000+60000)\div 12=35666$ lbs. which causes the following strains in the chords (see art. 84 for method of ascertaining strains):

$$BC=254654, \quad EF=381980$$
$$CD=318317, \quad FG=381980$$
$$DE=360759,$$

whence comparing with the maximum strains given in the table, we find that for BC and CD, we must add 10 p. c., for DE, $9\frac{1}{2}$ and for EF and FG, 9 p. c. to strains just found to get the corresponding maximum strains. The percentages are greater, except for end panels, than for the simple systems (see art. 52); hence a comparison of weights based on the same percentage, is favorable to the compound system, as drawn in Fig. 9, at least.

90. It is worthy of note that *the strains in the chords are greatest where the shearing force is zero.*

This is evident from the reasoning in art. 83: for as the increment of strain is, *the shear on the tie* $\times$ *tan i; where* the shear on the tie is zero, the chord strain is a maximum. Thus, in Fig. 10, since $s=o$ on tie Fh, there is no increment of strain to add to the strain on EF, at F. At E, $\frac{1}{2}$ w *tan i* is added to the strain on $\overline{DE}$ etc. We see then, that $\overline{EG}$ is more strained than any other part of the upper chord.

Similarly for irregular loading.

The above result is true, irrespective of the number of panels, hence for an indefinitely great number, as we may suppose a *solid beam* made up of.

This result must not be confounded with that of art. 64, where the object was to find that position of the load for which a particular chord piece would be strained most.

91. Let us now estimate the whipple as a *deck* bridge with leaning end ties,

trusses 14′ apart from centre to centre. Thus in Fig. 9 extend the upper chord to the abutments at A and M, discard Bc *a*B and *ab*; draw the ties *b*A, *c*A and the post B*b* (similarly at the other abutment) and conceive the load on the upper chord. The chord strains are the same as for the through bridge, Fig. 10; the maximum shear on the ties is the same as before, but the maximum strain on a post now is when the front engine is directly over that post, or two panels nearer the abutment than before, thus increasing the strains on the post over those formerly obtained. On this account θ is not the same for the posts as before. The results are entered in the following abridged table of weights, from which the Bill of Materials is made out as before. To avoid mistake in determining "*min. B*," the partial trusses may be drawn separately, when the principles of art. 27 apply directly:

Piece.	d	$\frac{l}{d}$	th	Strain.	θ.	b.	Area.	Length.	No.	k.	Weight.	Totals.
	″		″								lbs.	
U. Chord, $\overline{AB}$	$13\frac{1}{3}$	15		193589	.39	9050	20.1	$\frac{100}{6}$	4	$\frac{10}{3}$	4467	
BG	"	"		1858500	"	9270	200.5	"	"	"	44556	49023
Posts, B*b*	12	28	1	137000	.3	5840	23 5	28	"	"	8773	
C*c*	"	"	$\frac{9}{16}$	116700	.3	5840	20.	"	"	"	7466	
D*d*	"	"	$\frac{1}{2}$	97750	.25	5610	17.4	"	"	"	6496	
E*e*	10	34	$\frac{5}{8}$	78800	.17	4400	17.9	"	"	"	6683	
F*f*	"	"	$\frac{1}{2}$	61240	0	3750	16.3	"	"	"	6085	
G*g*	"	"	$\frac{3}{8}$	46000	0	3750	12.3	"	2	"	2296	37799
Lower Chord				1346987	.39	10420	129.2	$\frac{100}{6}$	4	"	28711	28711
Ties, A*b*				159605	.3	9750	16.4	32.6	"	"	7128	
A*c*				181235	.3	9750	18.6	43.5	"	"	10788	
Other ties (as before)								43 5	"	"	35954	53870

Bill of Materials.

Whipple Truss (Deck)—200′ span—28′ deep.

	lbs.
Upper chord and posts.......	86822
20 p. c. for castings, &c.......	17364
Ties and lower chord.........	82581
15 p. c. for bolts, &c.........	12387
Lateral tie rods and struts.....	11400
13 floor beams, 24″ deep......	22630
Iron stringers, 26″ deep.......	60000
Rails, cross ties, &c...........	33200
Total weight................	326384
Assumed weight...........	336000
	9616

MINIMUM MATERIAL.

92. The most economical inclination of the web ties, irrespective of the rest of the bridge, is easily found to be 45°. Thus call x the height of truss, d the horizontal distance between the extremities of the tie, i its inclination to the vertical, and s the shearing force on it. The strain on the tie is thus s sec. i; the cross section s sec. $i \div b$, and as its length is $\sqrt{d^2+x^2}$ its volume, is since sec.

$$i=\sqrt{\frac{d^2+x^2}{x}},$$

$$V=\frac{S}{b}\,\frac{d^2+x^2}{x}$$

which is a minimum for $x=d$, or when $i=45°$: *i. e., the material in the web ties is a minimum when they are inclined* 45° *to the vertical.*

93. The same would be true for the web struts, if b was assumed constant for them, but $b =$ the strain per square inch allowed, diminishes with the length of the strut, and the above simple relation does not hold. The general law of maxima and minima is this: that any function of a single variable is a maximum or a minimum for those values of the variable derived by placing the first differential coefficient of the function equal to zero. Thus, $v=$ a maximum or a minimum in the eq. above when

$$\frac{dv}{dx}=\frac{2x^2-d^2-x^2}{x}=o \quad \therefore\ x=d$$

It is evident that $x=d$ gives a min.

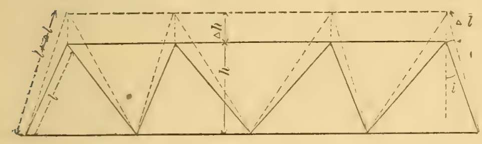
It is proved by noting that $\frac{d^3v}{dx^2}=\frac{2d^2}{x^3}$ is positive; for as the second differential is [$\pm$] the function is $\left\{\begin{matrix}\text{a min.}\\ \text{a max.}\end{matrix}\right\}$ for that value of the variable.

94. Having given for a truss with parallel chords, the *span*, *loads*, *panel lengths*, *pattern*, *details*, and *formulæ for* "b"—the unit strains required the most economical height of truss? Denote the weight of the material that varies with the height of the truss (since it is a function of h), by F (h). This material is such as given in preceding tables, as computed from the strains on web and chords. The castings, both etc., transverse bracing, flooring system, pins and loops, do not vary perceptibly with h, hence F (h)= weight of material computed *on* chord and web strains only; which is easily selected from the table of weights. Now, if F (h) is a minimum we must have

$$\frac{d\mathrm{F}h}{dh}=\lim\frac{\mathrm{F}\,(h+\triangle h)-\mathrm{F}h}{\triangle h}=o \quad . \quad . \quad (10)$$

95. Denote the weight of upper and lower chords, that varies with h, by

FIG. 11.



$\mathrm{W_c}$; also denote the variable part of the weight of a web member by w, its inclination to the vertical by i and its length by l.

Now change the height of the truss (see Fig. 11) to $h+\triangle h$ and call the new value of l, $l+\triangle l$.

96. As by assumption, the panel lengths remain the same as well as the diameter of the upper chord, the strains in, and hence the weight of, the chords are now $\frac{h}{h+\triangle}$ of the first, h and $h+\triangle h$ being respectively the former and present lever arms of the chord strains.

∴ *New weight of variable material in chords*,

$$\mathrm{W'_c}=\mathrm{W_c}\,\frac{h}{h+\triangle h}=\mathrm{W_c}-\mathrm{W_c}\,\frac{\triangle h}{h+\triangle h}\quad . \quad . \quad . \quad . \quad . \quad (11)$$

97. If S denote the shear on the web member, whose weight (the part that varies with h) was w, inclination to vertical i and length l, the former strain on it was sec. $i=\mathrm{S}\,\frac{l}{h}$ and hence its volume was $\frac{\mathrm{S}\frac{l}{h}}{b}l=\frac{sl^2}{bh}$.

The new volume is similarly,

$$\frac{\mathrm{S}(l+\triangle l)^2}{b'(h+\triangle h)}$$

in which, for struts (see art. 53)

$$b=\frac{38500(1+\theta)}{\left(4+\frac{1}{10}\,\frac{l}{d}\right)\left(1+c\frac{l^2}{r^2}\right)}$$

and b' equals the same expression on changing l to $(l+\triangle l)$. For ties $b=b'=7500(1+\theta)$.

Hence *the new weight of the variable material in the web member*$=w\times$ratio of new to old volumes

$$=w\frac{(l+\triangle l)^2}{l^2}\cdot\frac{h}{h+\triangle h}\cdot\frac{b}{b'}\quad . \quad (12)$$

Actually dividing b by b'; for struts, we get

$$\frac{b}{b'}=1+\frac{\frac{\triangle l}{10d}\left(1+\frac{cl^2}{r^2}\right)+\left(4+\frac{1}{10}\,\frac{l+\triangle l}{d}\right)(2l+\triangle l)\frac{c\triangle l}{r^2}}{\left(4+\frac{1}{10}\,\frac{l}{d}\right)\left(1+c\frac{l^2}{r^2}\right)}$$

$$=1+k\triangle l.$$

For ties this ratio is 1. Hence to avoid complication, simply notice that for ties the fractional term k, in the value of $\frac{b}{b'}$ for struts is zero, and as a consequence, when a tie is considered, the term m given below is zero. Now substitute the above value of $\frac{b}{b'}$ in (12) and reduce.

The first term of the 2nd member must now be written,

$$w\frac{(l+\triangle l)^2}{l^2}\;\frac{h}{h+\triangle h}$$

$$=w+w\,\frac{2hl\triangle l+h\triangle l^2-l^2\triangle h}{l^2h+l^2\triangle h}$$

So that the new weight of the web member is

$$\left(w+w\frac{2hl\triangle l+h\triangle l^3-l^2\triangle h}{l^2h+l^3\triangle h}\right.$$
$$\left.+w\frac{(l+\triangle l)^2}{l^2}\frac{hk\triangle l}{h+\triangle h}\right)=w'$$

and the sum of these, for the whole web we indicate by $\Sigma w'=\Sigma w+\Sigma$, &c.

98. Now, $F(h)=W_c+\Sigma w$

$$F(h+\triangle h)=W'_c+\Sigma w'$$

$$\therefore\ \frac{F(h+\triangle h)-F(h)}{\triangle h}=-\frac{W_c}{h+\triangle h}$$
$$+\frac{\Sigma w'-\Sigma w}{\triangle h}$$

Now by the principles of limits; *lim.* $\frac{\triangle l}{\triangle h}=\cos. i$, as $\triangle h$ and therefore $\triangle l$ diminish indefinitely.

Hence for a minimum weight of bridge,

$$\frac{dFh}{dh}=\frac{-W_c}{h}+\Sigma\left(\frac{2h\cos. i-l}{lh}\right.$$
$$\left.+\cos. i\times lim.\ k\right)=o$$

The *lim.* k we find by making $\triangle l=o$ in the value of k. Now since $\cos. i=\frac{h}{l}$, the above becomes on multiplying through by h

$$W_c=\Sigma\left(\frac{2h^2}{l^2}-1+\frac{h^2}{l^2}(lim.\ k)\ l\right)w$$

Now, $\frac{2h^2}{l^2}-1=2\cos.^2 i-1=\cos. 2\ 1$

And

$$(lim.\ k)\ l=\frac{\frac{l}{10d}\left(1+e\frac{l^2}{r^2}\right)+\left(4+\frac{1}{10}\frac{l}{d}\right)\frac{2cl^2}{r^2}}{\left(4+\frac{1}{10}\frac{l}{d}\right)\ \left(1+c\frac{l^2}{r^2}\right)}$$

Or putting $(lim. k)\ l=m$, and reducing:

$$m=\left\{\frac{\frac{l}{d}}{40+\frac{l}{d}}+2\frac{c\frac{l^2}{r^2}}{1+c\frac{l^2}{r^2}}\right\}\ .\ .\ .\ (13)$$

whence we find the following simple relation:

$$W_c=\Sigma w\left(\cos. 2\ i+\frac{h^2}{l^2}m\right)\ .\ .\ .\ .\ (14)$$

$\therefore$ *When the truss has the most economical height, the variable weight of the two chords must equal the sum of all the terms found by multiplying the variable weight of each web member by the cosine of twice its inclination to the vertical plus a term varying with the ratios of h to l and of l to d; noting that for ties, or posts where b is taken constant, this last term* $\left(\frac{h^2}{l^2}m\right)$ *becomes zero.*

For vertical members, $i=o$, $\cos. 2\ i=1$ and $h=l$.

99. For $i<45°$, $\cos. 2\ i$ is $+$; $i=45°$, $\cos. 2\ i=o$; $i>45°$, $\cos. 2\ i$ is $-$.

The above result is true for any pattern of truss whatever with parallel chords *in which* the strain on the chords varies inversely as the heights and the shear on any web member is not altered by a change of height.

The result then, it seems, applies to all usual forms of trusses with parallel chords.

100. Let us draw a few general conclusions from our formula :

1/. The depth of deck bridges with vertical end posts should be less than that of through bridges of *same design*, since the posts are heavier and thus W_c must be greater to satisfy eq. 14, which requires a lower truss. With no end posts for the deck bridge, if the web is thereby lighter the reverse may be the case.

2/. The greater the number of panels, the heavier the web, for the same height, which requires a lower truss to bring about the equality of eq. 14 (supposing W_c for the same height to be the same for any number of panels, which depend upon the relative unit strains of upper and lower chords).

3/. Continuous girders should have a less depth than simple girders, since for same weight of web, it is known that M_c is less than for a simple girder.

4/. Trusses with two or more web systems should be built deeper than similar designs with one web system, since *cos.* $2\ i$ is nearer o in the first case, hence W_c should be less and the truss higher.

101. If we suppose b (=strain per square inch) *constant* for braces as well as ties $m=o$ and eq. 14 becomes

$$W_c=\Sigma w\ \cos. 2\ i\ .\ .\ .\ .\ .\ (15)$$

In Van Nostrand's Magazine for Jan. 1877, p. 42, is an article by Emil Adler, C.E., on the most economical depth of girders, in which he deduces the equivalent of eq. 15. The general method fol-

lowed above is founded upon that of Mr. Adler; but it will be found that the supposition that b is constant will not give correct results in practice, hence I gave b the variable value, art. 97, and find the results to agree closely with practice. This should be so, since the value of b assumed agrees closely with values now used in America.

102. If all the web members are inclined 45°, as in the Warren girder $cos. 2\ i=o$ $\therefore$ $W_c = o$ or the height of the truss is ∞. Hence 45° is not the most economical angle—on the supposition that b is constant—for this truss. It is hardly probable that eq. 14 would change this conclusion, which is different from that often given in text books.

103. *Applications.*—In the Triangular Through Truss, Fig. 7, it was assumed that the unit strains are constant for all members but the three braces in the half truss, hence $m=o$ except for braces 1, 3, 5.

From the table art. 42 we find

Weights of chords $= W_c = 74{,}947$
" vertical members $= W_v = 14{,}336$
" ties and counters $= W_t = 29{,}580$
" 3 braces $= W_b = 46{,}879$

Now, $i=30°46'$ $\therefore$ $cos.2i=.477$; and for 3 braces, $\frac{l}{d}=30$; also in eq. 13 for "hinged ends," &c., $c\frac{l^2}{r^2}=\frac{4}{9000}\left(\frac{l}{d}\right)^2$ and, $\frac{h^2}{l^2}=.738$. Hence for the 3 braces, $m=\frac{3}{7}+\frac{4}{7}=1$;

$$\Sigma w(\cos. 2'2+\frac{h^2}{l^2}m)=46879(.477+.738) =56{,}958$$

Also

$$W_t \cos. 22'=31280\times.477=14920$$

For the vertical members cos. $22'=i1$

Now summing the results, we should have according to the rule of art. 98,

$$W_c = W_v + W_t \cos.2\,i + W_b\left(\cos.2i\frac{h^2}{l^2}m\right)$$

But the numerical values give,

$$W_c = 74947 < 14336+14110+56958 =85404.$$

104. With a less height W_c would be larger. Let us then try $h=27$ ft.

It is far more direct now to compute the new weights of chords and web from eqs. (11) and (12).

Thus in eq. (11) making $\triangle h=-1$, we find the new weight of the chords to be,

$$W'_c = 74947\ \tfrac{28}{27}=77723.$$

Similarly, the new weight of vertical members is,

$$W'_v = 14336\ \tfrac{27}{28}=13824.$$

From eq. (12) making $\frac{b}{b'}=1$, we get the new weight of ties and counters,

$$W'_t = 29580\left(\frac{31.7}{32.6}\right)^2.\tfrac{28}{27}=29000.$$

And from the same eq. (12) we find the new weight of braces 1, 3 and 5 to be

$$W'_b = 46880\left(\frac{31.7}{32.6}\right)^2\frac{28}{27}\cdot\frac{b}{b'} = 44455.$$

The braces were assumed, as before, of $13\frac{1}{16}''$ diameter. The new length of a brace is $31'.7$; hence

$$\left(\frac{l}{d}\right)=29 \text{ and } \frac{b}{b'}=\frac{393}{406}.$$

We find, $cos.\ 2\ i=.448$.

Apply eq. (14) again to the new weights:

$$W'_c = 77723\ (13824+29000\times.448 +44455(.448+.706)=78117$$

The truss may be one or two-tenths of a foot lower there for economy. The amount saved though is not worth the computing, for in the change from a height of 28′ to one of 27′ the amount saved is only 740 lbs. as we find from the above.

The time may more profitably be spent in ascertaining the best diameters of compression members for economy, regard being had to the castings and pins at the same time.

105. For the whipple through truss, Fig. 9, we get from the table, art. 85

$$W_c = 76208$$

Tie $\overline{Bc}\times\cos.\ 2\ i=6064\times.477=2892$

(Other ties and counters) $\times\cos.\ 2i'$ $=36000\times-.174=-6264$

$$\therefore\ \Sigma w_t \cos.\ 2i=-3372$$

Regard b as constant for posts $\overline{Ff}$, $\overline{Gg}$,

$$\because\ W_v = \overline{Bb}+\overline{Ff}+\overline{Gg}=7193$$

$$\text{Also } W_p = \overline{Cc}+\overline{Dd}+\overline{Ee}=17106$$

For these posts $\frac{l}{d}=34$, and for a "one pin end," $c\frac{l^2}{r^2}=\frac{1}{3000}\frac{l^2}{d^2}$ and $W_p\,(\cos.\,2i+m)=17106\,(1+\frac{34}{74}+\frac{10}{18})=34469$

For the brace Ba, we have as before,

$$W_b\,(\cos.\,2i+\left(\frac{h}{l}\right)^2 m)=20495(.477+.738)$$
$$=24901$$

Now from art. 98 we should have for economy

$$W_c=\Sigma w_t\cos.\,2i+W_v+W_p\,(1+m')$$
$$+W_b\,(\cos.\,2i+\left(\frac{h}{l}\right)^2 m)$$

whereas we find,

$$W_c=76208>-3372+7193+34469$$
$$+24901=63191$$

W_c is too great, hence the height should be greater. A height of 29 feet may now be tried.

The influence of the diagonals is very small in our equation, since *tan* $dBb=50°$ or nearly 45° (art. 92). In a similar manner it is found that the height of the Whipple Deck Truss should be increased to 29 feet.

106. The Pratt Truss, through bridge, was next computed, for same span, loads, No. panels and height (28′) as before. The strains have already been given. The end brace was inclined, as in Fig. 9. Using the lettering of that Fig. the posts $\overline{Cc}$, $\overline{Dd}$ were given a diameter of 12″; the other of 8″ to 10″, the end brace and chord as before.

On making out a "Bill of Materials," the total weight of bridge was found to be 333,800 pounds.

From the table of weights,

$$W_c=75{,}095 \text{ pounds.}$$

Ties and counters $=W_t=36914$,
also $\cos.\,2i=.477$

$$W_v=\overline{Bb}+\overline{Ee}+\overline{Ff}+\overline{Gg}=18654$$
(b constant)

End brace, $M_b=20495$ (as before)

$$\text{Posts}\begin{Bmatrix}Cc\\Dd\end{Bmatrix}=W_p=18174.$$

For these posts $\frac{l}{d}=28$ and,

$$W_p\,(\cos.\,2i+m')=18174(1+\tfrac{7}{17}+\tfrac{3}{7})$$
$$=33374.$$

Then for economy we should have

$$W_c=W_t\cos.\,2i+W_v+W_b$$
$$\left(\cos.\,2i+\frac{h^2}{l^2}m\right)+W_p\,(1+m).$$

Actually we find,

$$W_c=75095<17608+18654+24901$$
$$+33374=94537$$

The height is too great, $h=26$ may be tried.

107. On computing, by eqs. (11) and (12), the new weights of the Whipple Truss for a height of 29′ and of the Pratt Truss for a height of 26′, we find a saving in the former of 544 pounds, and in the latter of 714 pounds over the weights of the respective trusses 28′ high.

From eq. (14) we also ascertain that the Whipple Truss, *for the diameters taken*, might have a height of $\frac{2}{10}$ foot, say over 29′ with economy. The Pratt has within a tenth of a foot of the most economical height for the dimensions given.

Errata in July, 1878, Number.—Page 81, art. 43 $(14+1\frac{1}{2})$ should be $(14+3)$.

On page 82, 2d column, line 3, for 63866 lbs., read 63886 lbs.

On page 82, 2d column, line 4, for 33693 lbs., read 38963 lbs.

A correspondent of the *Times* writing upon tests for diamonds says: "The late Mr. Babinet of the French Institute, in his 'Etudes et Lectures (Vol. 3, p. 38), has the following: 'I shall mention a very delicate optical character that immediately draws a line of demarcation between diamonds and all colorless gems —I mean double refraction. In looking through a transparent stone at any small object, such as the point of a needle or a little hole made in a card, one sometimes perceives the object double, as if the hand held two needles, or the card had been twice perforated. Such is the case with all white or colorless gems; but never with the diamond. Every stone, therefore, that exhibits double refraction is thereby excluded from the rank of diamonds."

GEOGRAPHICAL SURVEYING.

By FRANK DE YEAUX CARPENTER, C.E., Geographer to the Geological Commission of Brazil.

Contributed to VAN NOSTRAND'S MAGAZINE.

II.

THE ODOMETER.

The distances from station to station of the meander are measured by the odometer, an implement of survey which, in some of its forms, has been long in use in Europe, and has of late years received especial attention and improvements in the reconnoissances and other geographical surveys carried on by the War Department of the United States of North America. In this service it has been adapted to the severe conditions of travel in a new country. It has been strengthened so as to withstand any shock or fall to which it may be subject. The recording apparatus is made so compact and simple that there is no danger of disarrangement there. Instead of the old laborious process of pushing it by hand, the wheel has been fitted with shafts, so as to be drawn by a mule, and so efficient is the method of attachment that the odometer can follow any route, however rough, precipitous, or narrow, that will admit of the passage of a pack-mule.

In its simplest and best form the odometer vehicle is a solitary wheel, a little more than a meter in diameter, or about the size of a light carriage-wheel. It is strongly constructed of the best material, and is braced by opposite inclinations of alternate spokes, so as to be uninjured by the heaviest jars and collisions. A pair of shafts are attached to it, and into these a strong and steady mule is firmly harnessed by straps from above and underneath. The vehicle is close in the rear of the animal, and the shafts are made short and heavy, and in this manner the wheel is preserved in a plumb or upright position as it runs, not swaying from side to side. The length of the circumference of the wheel being accurately known and the number of revolutions being recorded by the attached apparatus, it is a simple matter to learn the distance between any two points.

The recording instrument hangs in a cylindrical box which is strapped to the wheel. It consists of a mechanical combination attached to a heavy block of metal, whose center of gravity is at one side of the axis to which it is suspended. As it is free to revolve upon this axis it always maintains a vertical position, while its box turns with the wheel, and the apparatus scores the number of revolutions, of which it is capable of recording 9900, or a distance of about forty kilometers, when it begins anew.

USEFULNESS OF THE ODOMETER.

This detailed description of the odometer is in accordance with the promise, made in the early part of this article, to dwell upon the novel features of this work, even to the exclusion and apparent neglect of others, already well-known, which are really of greater importance. Still it would be difficult to over-estimate the usefulness and practical value of this instrument. It requires but little technical knowledge to use it and to conduct the meander survey which accompanies it, and any person educated in the simplest rudiments of surveying, is competent for this kind of work.

For this reason every party of scientific exploration and reconnoissance, every preliminary survey for railways, and every marching body of troops should consider its outfit incomplete without the implements of an odometric survey. Aside from the mass of notes and sketches that would be accumulated by them, and the itinerary maps that would result, in the item of distances alone, the country would be more than repaid for the cost of these surveys. As a means of mensuration the odometer will determine distances *en route*, as the wagon travels, more truthfully than the chain itself. These, being published, are of profit, not only to the ordinary traveler, but also to the general government, whose agents and officials, in one capacity or another, are constantly passing to and fro.

ERRORS OF THE ODOMETRIC SURVEY.

Nor is there any very great error in the ordinary surveys which the odometer is likely to be called upon to perform. Having the geographical positions of two towns forty kilometres apart, they may be connected by an odometric survey, the plot of which can be adjusted between these two positions so that no intermediate points will be appreciably out of place on a map of the usual scale. Since this is a map for practical use and for the public good, it fulfills its purpose as well as if its distances had been measured by the most refined methods.

The great objection to its use is the tendency towards the accumulation of error in an odometric meander, and the farther it is from the known point which is its origin, the greater is the probable error of any position determined by it. Therefore, in a prolonged journey, or in a general survey of the country, the odometric position should frequently be verified, or checked and rectified, by connection with known points. This can be accomplished by making a station at some point on a railway, boundary, or other line of accurate survey ; by astronomical observation, which, however, if taken with a sextant, is often less reliable than the meander itself, or by making a meander station dependent upon the accompanying triangulation, by means of the three point problem. The last method, which is by far the most reliable, will be explained further on.

ERROR OF DIRECTION.

The meander is affected by error of two kinds, of direction, and of distance. The former, in its most serious nature, is incurred in the survey of a tortuous valley, whose general course must be accepted, or in crossing a timbered country, or a pathless plain, where the surveyor is in a constant state of uncertainty as to whither he is to go, or, taking a back sight, as to whence he has come. Sometimes the engineer is obliged to keep his eye on the sun and get a general idea of the course from that. Or, in traversing a dense forest, he may find himself compelled to resort to the paradox of sighting upon a sound; that is, he allows the pack-train to keep a certain distance in advance, and from time to time he directs his telescope to the tinkling of the bell which is carried by the horse that leads the train. It must be confessed that these make-shifts are loose methods of survey, but they are better than none, since they give the prominent directions and the distances between streams, divides, etc., and months afterwards, when the engineer comes to make the map and lay down upon it the trail of that day's march, he will find the poorest and most incomplete notes more reliable than his present memory and judgment.

Even under the most favorable circumstances it will seldom be possible to direct the telescope with greater precision than to the nearest degree, nor, as a consequence, will it ever be worth while to record any fraction of a revolution in the odometer. A road does not usually change direction by an abrupt angle, but by a gradual curve, and the bearing is made approximately tangent to that curve. Or, in the survey of a stream, it is not known on which side the trail will run at some point a kilometer in advance, and so the approximate center of the valley is accepted. But if there should be a solitary tree, bush, house, rock, or other prominent object fortunately situated for a station, the course will be made closely tangent to that, a reading of instruments will be taken upon arriving there, and, going on to the next station, the engineer will take a back-sight to the same point. In general the system of back-sights will be found more satisfactory than that of foresights, as it is easier, on a strange route, to tell whence you have come than to decide where you are going.

ERROR OF DISTANCE.

This error of direction, it will be seen, is thrown by the law of chance alternately to the right and left of the true line, and so has a tendency in its elements towards mutual compensation, and in a measure it corrects itself. But not so the error of distance, which is always plus, and cumulatively so. The test of the odometer wheel, by which its number of revolutions per kilometer is ascertained, is made upon a level surface and along a staked alignment, giving a result almost absolutely correct. In practice, however, the vehicle climbs acclivities of every grade, tacks hither and

thither as it follows the trail up the mountain, winds incessantly in its route through the forest, and is disturbed by frequent jolts and collisions along the rocky flow of the canon. In a theoretical traverse the straight line between any two stations is determined, but in an odometer survey the measuring implement usually follows a beaten path, and the route distance, by road or trail, is rarely the shortest distance between two points. Hence, an "overrun" in its record, which can only be remedied, and that approximately, by the judgment of the surveyor, who is taught by experience to estimate very closely the surplus in a given run, and who applies a correction accordingly.

Still, to such perfection has the odometer survey been brought, that it is a common occurrence for a skilled worker to meander a closed circuit of one hundred kilometers, and plotting the route, to find the plot also close within a small fraction of a kilometer. Even this error, being judiciously distributed in the process of adjustment, different weights being assigned to different runs, according to their probable accuracy, may be reduced so as to be practically imperceptible.

OCCURRENCE OF MEANDER STATIONS.

No general rule can be given for the frequency of meander stations, but in ordinary country they will average perhaps one to the kilometer. In this all will depend upon local circumstances and exigencies. In the survey of a long and hidden valley, affording no opportunity for checks, especial care must be taken to preserve the integrity of the meander, and the stations must be especially frequent; but in a survey by a direct line across the plain two or three stations a day may be sufficient. In a winding path up a mountain side a dozen stations may be necessary if there are no chances for checks; but if the ends of the trail, at the top and bottom of the mountain, can be located by the three-point problem, the intermediate route can be neglected, being, at most sketched in by the eye.

There are two considerations to govern the occurrence of stations; first, to preserve the continued accuracy of the survey, and second, to note the local geographical features which may be encountered. For the latter purpose stations will be made at the center of every village, at every country-house of importance, at the crossing and divergence of streams, roads and trails, at the opening of a valley, at the foot and summit of a mountain, and at the many other geographical vantage-grounds which the practical engineer will know how to select. But in this, as in the other departments of the survey, too punctilious zeal may defeat its own interests by causing delay, and the surveyor who is too scrupulously exact in the forenoon may have to virtually abandon his task in the afternoon, in order to reach a suitable camping-ground by night.

SCOPE OF THE MEANDER SURVEY.

The zone of country considered from a meander line may extend to the farthest visible point, as a series of sights upon a mountain even twenty-five kilometers away will give its position to a close approximation; but its principal intent is the preparation of a narrow route map, the areas encompassed by whose windings will be filled in from the topographical stations. Since, from its nature and narrow scope, it is fuller and takes cognizance of objects more minute than can be noticed in the other systems, in this the engineer is liable to a charge of partiality, reproved in the early part of this article. But this is not partiality in one field at the cost of neglect in another, and the greater excellence of this work is so much clear gain. Moreover, since the meander is usually by way of roads of frequent travel, and since a map is useful, and should be excellent, exactly in proportion to the number of people who are guided by it, it is well that the meander plot should excel in completeness those almost inaccessible parts which will never be seen except by the hunter or bandit.

MAKESHIFTS IN THE SURVEY.

In a forced march of forty kilometres or more, the meteorologist and odometer recorder, the safe carriage of whose implements requires a slow and steady gait, may proceed at a walk after taking their readings at a meander station, which task will occupy them but a few minutes, while the surveyor lingers behind to make

the necessary sketches and observations, and then, riding at gallop, overtakes his comrades before the next station is reached. Many such shifts as this are known to the practical and energetic geographer, who learns to emancipate himself from too close dependence on the text-books of surveying, some of whose rules are very common-place and pedantic, and brings into play his powers of ingenuity and invention, to adapt himself to the peculiar circumstances by which he may be surrounded. If he finds himself alone, out on some trip of hasty reconnoissance, or on some hunting excursion on which he could not carry both rifle and transit, he draws from his watch pocket an aneroid, and from his saddlebags a pocket compass or an altazimuth, and his equipment for survey is complete; as for distances, he can estimate them, or determine them by the time they take, calculating at the rate of five kilometres an hour, or, better still, by counting the steps of his horse and allowing six hundred double paces for a kilometre.

In a geological survey of Brazil very much of the travel and exploration is necessarily done by water, as the outcrop of the various formations is most favorably shown upon the banks of the rivers, along which there is frequently no passable route by land. Here the stadia may be used, provided there are two or more boats in the party, or, in the less important instances, the methods of obtaining distances by estimation or by time would have to suffice. In either case the surveyor should lose no opportunity to emerge from the trough of the stream, or to ascend some eminence, and insure his position by observations upon three or more known points. Should these be wanting, he should resort to the sextant and to its use in astronomical determinations.

Since the attention of the geologist is in great part absorbed in the duties peculiar to his profession, he cannot usually carry any but the lightest and most convenient implements of survey, and since these are amply sufficient for his geological notes of dip, strike, trend, etc., it is a matter of expediency to make them answer for his geographical work as well. With the engineer, however, there rarely comes a necessity for being separated from his portable transit, which admits of being firmly set on its tripod, and from which angles, either horizontal or vertical, may be accurately read to the nearest minute. And in the general geographical plan it is wise to deprecate as far as possible the employment of unreliable pocket instruments, or of the devices for learning distances that have been detailed above. Since nothing is to be gained in time by their use, and very much may be lost in accuracy, the engineer should teach himself to consider, that any method less complete than that of the portable transit and odometer is but a temporary expedient and makeshift, serving an excellent purpose when all other means fail, but not to be relied upon as a permanent constituent of the survey.

CO-OPERATION OF THE TRIANGULATION AND MEANDER.

While the meander survey is an excellent apprenticeship for the young engineer, it should not be despised, as an occupation, by even the director of the triangulation. Humble as it is, it performs a task in the geographical plan which no system of triangulation can be relied upon to perform in a rapid work of this nature. It enables the survey to reach any point, however remote and secluded, and to determine its positions it makes the map complete in all of the details which are so useful to the traveler; and as an agent in what we may call the practical or economical branch of geography it is without an equal.

It is dependent upon the triangulation, it is true, but then the dependence is mutual. The full benefit of either can only be secured through the co-operation of the two. As without the triangulation the map is unreliable, so without the meander it is incomplete. To use a homely illustration, the triangulation may be compared to the framework of the dwelling, and the meander to the intermediate filling of wall or other substance which makes the house habitable, and is a shelter to the inmates. This frame, if its lines are true and its angles correct, is a beautiful thing for the artisan to contemplate, but without its completion of walls and furniture, it is of no real benefit to the world. In the same manner a bare triangulation scheme may

be an interesting study to the geographer himself, but to the traveling public and the people at large, it possess neither interest nor value. On the other hand, as the frame of the house is an absolute necessity to it, securing and sustaining it in its proper proportions, so is the triangulation the rigid frame work of the map and the skeleton to which the useful data of the meander are attached.

CHECKS BY THE THREE-POINT PROBLEM.

Since the meander is from its very nature so hasty and loose, the system of frequent checks can alone make it reliable, and at intervals of every few kilometres, and especially at the crossing of divides and other eminences from which there is a broad scope of country visible, connection should be made with the triangulation. Each of these stations then becomes a new initial point, at which the survey begins afresh and the error again begins to accumulate.

This rectification is accomplished by the use of the three-point problem, a geodetic determination which, as a means of locating topographical stations, and as a connecting link between the meander and the triangulation, is of the highest importance in geographical surveying. Having three triangulation stations in sight, and favorably situated, it is possible for the observer to determine his position in a few minutes of time and by the simple operation of reading the two angles included by those three stations. From these and the data pertinent to the triangulation stations he can compute his distance from them, and hence his present latitude and longitude. Or, plotting these angles from any center on a piece of tracing cloth, he can lay this upon the projected map and swing it around until each of the three plotted rays covers its proper triangulation point, when this center will indicate the position of the three-point station, as it is called. For this graphic determination not only three points, but four, and even more, if they are visible, should be observed, as a greater number facilitate the operation and insure the accuracy of the result.

This method of trilinear determinations cannot be introduced too often. A three-point station in the streets of a settlement, at the forks of a road, or at the end of a mountain range, will locate these important places, and in camp, even in the center of a broad and vacant plain, there is no more profitable manner in which the engineer can spend his leisure time, before or after dinner, than by making a three-point station there and determining his position. Every camp thus fixed is a new and reliable origin at which the meander of the next morning will begin.

A SURVEY BY THREE-POINT STATIONS ALONE.

In some cases a successful meander may be carried on by three-point stations alone, when all other means would fail. Take, for instance, the rugged shores of a lake or bay, which are inaccessible except to a man on foot or in a boat. In the mountains on the other side of the water a series of triangulation stations stand up in full view. By means of these the engineer, working his way, transit in hand, from bay to bay, and from point to point, along the water's edge, makes three-point stations at all prominent changes of curvature, and, sketching in the intermediate shore, he determines its line by tangents and intersections, and thus secures a good survey of the coast. If there are islands out in the water they may be surveyed in the same way.

If the engineer was confronted with a piece of geography like the bay and islands of Rio de Janeiro, and if there were no roads along the beach to make direct linear measurements feasible, he could extend his triangulation to include all of the prominent peaks in the vicinity, and then, by means of three-point stations, he could rapidly trace in the shoreline. As the surroundings of Rio are so broken and irregular, the triangulation points could be made so numerous, that it would be difficult to find a spot on the beach, or mainland, or island, so secluded that some three of these stations would not be visible from there.

THE MEANDER PLOT.

Every three-point station, as well as every other meander station, should partake more or less of the nature of a regular topographical station; that is, contour sketches should be kept constantly on the plotted page as it progresses, and a continuous panorama of profile views,

drawn in a separate portion of the book, should accompany the survey, so that, as some geographical features are left in the rear, others may be introduced in advance.

As from one topographical station to its neighbor, so every distance from one meander station to the next should be considered a base to be used in the location of points useful in the structure of the map. The longer this base, the more distant may be the range of these views. In case several meander stations intervene between one observation and the following, this total intermediate distance becomes what is called a broken base, but it is none the less useful for all of that. The above considerations will influence the engineer in his choice of stations, which will always be situated in such positions as may offer the best advantages for the accumulation of whatever information he most needs.

THE DECLINATION OF THE COMPASS NEEDLE.

The variation of the compass needle, or, more properly, its declination, will be carefully watched throughout the survey, and determinations of its angle will be made from time to time; these will be more than usually frequent wherever there is suspicion of some attraction immediately local, arising from the presence of magnetite or other ore of iron, basaltic rock, or other disturbing influence. These determinations are important, not only in the reduction of the meander notes taken in this vicinity, but also for the practical use, both present and future, of the country at large. In addition, their results will aid the general cause of science in its investigation of the laws of terrestrial magnetism, and in tracing the course of isogonic lines around the world.

At every triangulation, topographical, and three-point station, the observer will note the direction of magnetic north, as indicated by the pointing of the compass needle. If his instrument has a double movement in azimuth, as all should have, it is well, for the sake of convenience, to first set the zero of the graduated limb upon the same point of the vernier plate, by the upper motion, and then, by means of the lower movement, bring the north end of the needle to the zero of its circle. His initial entry in his note-book will then be "Magnetic North, 0° 00′ 00″." This direction of the telescope being referred to some line proceeding from here, whose true azimuth will be found by subsequent computation, the magnetic azimuth or declination of the needle at that place will be determined; it will simply be the difference between the true azimuth of the line, reckoned from the north point of the horizon, and its apparent azimuth, or the vernier reading which he enters in his notes.

BY DIRECT ASTRONOMICAL OBSERVATION.

The declination of the needle will also be determined directly by astronomical observation in the evening at camp. For this purpose the engineer will select such nights, clear and still, as may appear to him most favorable, and such camping places as may most urgently require this information. A star as near as possible to the pole will be chosen, as, from its greater declination, an error in the latitude of the observer's place, and, from its slower motion, an error in the time of the observation, will result in less serious errors in the azimuth; and the smaller the polar distance of the star, the more convenient will be the observation and the computations which follow, and the more exact is the result likely to be. In the northern hemisphere α *Ursæ Minoris*, or *Polaris*, is almost always used, as it is at present only about 1° 20′ from the pole, and it possesses the additional advantage of a brilliancy of the second order. But south of the equator there are no available stars so favorably situated as this. The most southern one of any considerable size is β *Hydri*, of the third magnitude, whose polar distance is a little more than twelve degrees.

This would have to be accepted in a survey of this nature in preference to any of the less brilliant stars of greater declination, as the observations would have to be made frequently by engineers of little astronomical experience, and with instruments not especially adapted to this kind of work. Indeed, it might be necessary at times to use the small meander transit for that purpose; and it is seldom that the telescopes of even the theodilites for triangulation, as now constructed, are provided with the hollow rotation axis requisite for a proper illu-

mination of the diaphragm, without which it is difficult to see both cross-hair and star, unless the latter is of conspicuous magnitude.

Knowing, at least approximately, the latitude of the place, and also the declination of the star and its hour angle at the time of observation, its azimuth angle from the south point can be computed. But as the hour angle depends upon the local time at that place, and there is great room for error there, the observer, unless he has full confidence in his ability to make an accurate time-determination, should find the approximate minute of the star's greatest elongation, and follow it with the transit thread until it reaches the dead point in its azimuth motion, where it seems to stop a few moments between its advance and retrogression. Then, being at its greatest elongation, the sine of its azimuth angle is equal to the cosine of its declination divided by the cosine of the latitude of the place.

Should the star β *Hydri* not arrive at its east or west point at a convenient hour, as at certain seasons of the year it will not, the star *Canopus*, differing in right ascension about six hours, or α *Trianguli Australis*, of about sixteen hours greater right ascension, may be employed. These are respectively of the first and second magnitude, and hence are very well adapted to this purpose, but, owing to their greater polar distances, it would be necessary, in their use, for the observer to be especially sure of the correctness of his latitude.

The sun is not usually available for determinations of azimuth or time, as the engineer is generally upon the march throughout the day. The use of a star, however, admits of greater precision in the observations, while the resulting computations are less complicated, and, in the case of an azimuth determination, a south star is doubly convenient from the fact that its two daily elongations always come above the horizon, and whichever one occurs most opportunely may be used; or it may be possible at times to observe both, in which case it becomes unnecessary for the engineer to know his latitude. The same difficulty of latitude, may also be avoided by the method of equal altitudes of a star, taken at several hours before and after its meridian passage; the middle point between the two corresponding azimuths will be upon the meridian.

THE METEOROLOGIST AND HIS INSTRUMENTS.

In all of his travels the meteorologist will be the constant companion of the engineer, so as to be prepared to take observations at any point that the latter may designate. At the beginning of the field season he will be furnished with, at least,two complete sets of meteorological instruments, to be carried by himself and by others who may be appointed to assist him. Each set will be composed of a cistern barometer, an aneroid, maximum and minimum thermometers, pocket thermometers, and a psychrometer, consisting of two similar thermometers, one with its bulb capable of being moistened by the capillary attraction of a loose cord of cotton filaments leading to it from a cup of water, and the other dry, as in the ordinary instrument.

Prior to taking the field he will compare these barometers by a series of readings extending through several days, with some standard barometer whose error is known, in order to obtain the instrumental errors of the instruments at hand. Throughout the season, also, he will lose no opportunity for comparisons with any reliable barometers that may be encountered, as well as for frequent comparisons between these two. In this manner the time of any possible dislocation of the scale, or other source of error, will be determined.

As in the rough and rapid travel of a geographical survey, there is great liability to break the fragile glass tube which contains the heavy mercurial column, an extra supply of barometer tubes and mercury should be transported with the party, and also an assortment of tools and material for the filling, boiling, and fitting of a fresh tube. This is a delicate and difficult task, but it is one in which every meteorologist should be proficient. As full instructions for the use and repair of meteorological instruments have already been prepared by the Commission, it is needless to repeat them here.

METEOROLOGICAL OBSERVATIONS.

At every station of the survey, the meteorologist will read from his instru-

ments the data from which the elevation of that point may be subsequently computed. Nothing more is then needed for the precise determination of that station's position. The engineer has fixed it in latitude and longitude; the meteorologist, in its altitude above sea-level. The meteorological data will be more or less comprehensive and will be read from instruments more or less reliable, according to the geographical importance of the place at which they are taken. The more frequent the readings, and the more prolonged the series, the more trustworthy will the resulting mean be, and the less liable to be materially affected by errors of observation, and by those erratic fluctuations to which the barometer is subject, owing to the constantly varying atmospheric currents and other disturbing physical conditions to which it is exposed, and whose effect cannot be entirely eliminated by any formulas that it is possible to devise.

Beginning at the point of outfit' which, on account of the work of preparation and the measurement of the base-line, may be occupied some weeks or a month, hourly readings will be taken throughout the day and night for as long a time as possible. The cistern barometers will be read, as the height of the mercurial column is the basis upon which all barometrical determinations rest. The attached thermometer will be read, to learn the temperature of the mercury, and hence what correction must be applied to reduce it to the freezing point, at which all barometrical heights are compared. The isolated thermometer will give the temperature of the surrounding atmosphere, to be used in determining the mean temperature of the stratum of air intermediate between this and the reference station. And the psychrometer will reveal the amount of aqueous vapor in the atmosphere, and the influence of its pressure upon the height of the column of mercury. In addition to these, note will also be taken of the direction and force of the wind, the condition of the sky, the proximity of storms, and other atmospherical phenomena, as this information may give the key to some abnormal barometric oscillation which would otherwise have to remain unexplained.

HORARY AND ABNORMAL OSCILLATIONS.

The hourly observations will be continued throughout the day and night for the purpose of determining the amount of the horary oscillation at that place. This horary oscillation is a somewhat regular rise and fall of the barometer, occupying a period of twenty-four hours. The range of this fluctuation in some parts of the world is so great, that its effect upon the mercurial column may equal that which would be produced by a change of fifty meters in altitude. It is such that, if the successive heights of the column be represented graphically by a curve, this curve will show two daily maxima and minima, occurring at intervals of about six hours, the morning maximum being attained at about ten o'clock A. M. This horary curve, as it is called, varies with the latitude, altitude, and climate of a place, as well as with the different portions of the year. The value of the horary variation for any hour of the day is revealed by a study of the prolonged series of observations at that place, and may be assumed to be the same for all observations taken in the vicinity of that station and in the same season of the year.

The barometer is also influenced by the abnormal oscillation, apparently resulting from the progress of great atmospheric waves across the country, affecting the mercurial column by a gradual rise of several days, followed by a period of subsidence of about an equal duration. The effect of this disturbance can be eliminated, approximately, by taking the difference of the barometric readings at the beginning and ending of any one day of its rise or fall, and considering this as its amount for that twenty-four hours, a proportional part of which will be its value for one hour.

DETERMINATION OF HEIGHTS.

To obtain the altitude of the first station of the survey, a mean of the corrected heights of the mercurial column is compared with a corresponding mean of the same hours of the same days at some permanent station, whose elevation above the sea is definitely known, as, for instance, the Imperial Observatory at Rio de Janeiro. This, by a process of computation, gives their difference of

altitude, and hence the total elevation of the point in question.

Now, making this point of outfit a reference station, at which an observer is left with meteorological instruments to be read at stated intervals throughout the day, the party takes the field, and the traveling meteorologist reads a series of barometrical and other observations at the first camp and at all others to which they may come during the season. These will be compared, as before, with synchronous* observations at the reference station, and the differences of altitude will be calculated. At every topographical station, and station of importance along the meander survey, such as villages, fazendas, mines, mountain passes, divides, etc., and at all other points that may be designated by the engineer, the meteorologist will read the cistern barometer, the watch, the thermometer, and the psychrometer, and, for the purposes of comparison, the aneroid barometer as well. These isolated observations will also be referred to the main barometrical station at a distance.

But, on the occasion of the ascent of a mountain peak from a fixed camp, better results will be obtained by considering the camp a reference station in the determination of the altitude of the mountain. This ascent will necessitate the occupancy of the neighboring camp for two nights and a day at least, and perhaps longer, while the peak may be occupied only a portion of a day, during which time, however, there will be corresponding hourly observations at camp and mountain-top. Hence the altitude of the mountain will be most truthfully ascertained by referring it, by these synchronous observations, to the camp, and then the camp, in a similar manner, to the distant reference station.

HORARY CURVES AND REFERENCE STATIONS.

Whenever the party, or a portion of it, remains stationary in camp for a few days at a time, hourly observations day and night will be taken to determine the horary curve at that place; the longer the series, the better will be the result. Since the horary variations are constantly changing with altitude, country and climate, it is important to have as frequent determinations of them as can practically be made, so that no very great distance may intervene between the place where a table of horary corrections is constructed and the place where it is used.

For a similar reason it may be deemed necessary to establish and sustain a second meteorological reference station, if the field of the season's survey should be a wide one, or if it should vary greatly in the atmospherical condition of different portions of its area. No comprehensive rule can be given to govern the number of these reference stations; all must depend upon the judgment of the director of the survey, and the resources at his command. In general, the farther the place of an observation from its reference station, the less reliable will be its result. But, as an exception, let us take the example of a broad inland plain, separated from the sea and its influences by a wall of mountains, within which, upon the plain, the reference station is situated. In this case it may be more justifiable to refer to this station a point on the plain, five hundred kilometres distant, than one just over the mountains, only one hundred kilometres away. This is owing to the widely different climatic circumstances of inland and sea-coast, resulting in meteorological conditions so dissimilar that equal amounts of pressure cannot be relied upon as an indication of equal thickness of the atmospheric envelope.

THE ANEROID BAROMETER.

At the many stations of the meander survey that are comparatively unimportant, and that are occupied for a few minutes only, it will suffice for the meteorologist to read only his aneroid, watch, and thermometer. Although the aneroid is not a reliable instrument, yet it serves an excellent purpose where rapid and approximate work is sufficient. Since its principal use is in obtaining profiles of the meander routes, which will enable the engineer to properly distribute the

* It is well to distinguish between the meanings, as now understood, of the two words "synchronous" and "simultaneous." The term "simultaneous" is applied to observations which are made at the same absolute instant of time, as, for instance, upon the occultations and eclipses of the heavenly bodies. Synchronous observations are taken at the same hour of the day, local time, irrespective of the difference of longitude between the two stations. Therefore, observations can be both simultaneous and synchronous only when the observers are upon the same meridian. The word "simultaneous" belongs especially to the province of astronomy, whilst "synchronous" is most frequently used in connection with the phenomena of physical geography.

contour lines upon his map, and since, farther, the error of an aneroid will rarely exceed the vertical distance between two of these contours, the resulting inaccuracy upon the plot will be quite inappreciable.

The aneroid is to the cistern barometer what the meander is to the triangulation, that is, a means of filling in, which, while costing but little extra effort, is productive of very valuable results. The engineer who rejects the meander and the aneroid because they are not rigidly exact in their functions, will find himself reduced to the necessity of tracing in the roads and streams of his map, locating many of the villages, cross-roads, etc., and drawing in the contours from his judgment and memory alone; and it is safe to say that the conjectures of the most able and trained topographical intellect are by far less reliable than the figures of those humble instruments, the aneroid and odometer, when judiciously used.

At every camp the aneroids are compared with the cistern barometer, their scales are adjusted in compensation for any error that may have crept in, and the vertical element of the survey starts from a new and true datum plane when the march is resumed. At the end of the day's journey, also, they are immediately compared again, and the error accumulated throughout the day is noted, and, by a process of distribution along the day's profile, may be reduced to a minimum. Before and after every side trip, reconnoissance, or ascent of mountain, the aneroid is compared with the mercurial barometer, and thus, by a continual and careful watch over it, it may be relied upon to give results not seriously in error. But if left to itself and unchecked for any great length of time, or for any great distance of journey, or great change in altitude, this fickle instrument may continue to go astray, by a shifting of its scale, exhaustion of its spring, or from other causes, until its readings are hundreds of meters too high or too low. Even then, however, it may be of use to the geographer in drawing in the relief of the country, as the discrepancy is usually of gradual growth, and the relative altitudes during the progress of the survey, as, for instance, the height of a bluff above the neighboring valley, are sufficiently exact to be of much assistance to him in his plotting.

BAROMETRICAL RESULTS.

As to the reliability of altitudes determined by the cistern barometer, evidences and opinions differ, but those persons who are most thoroughly informed are generally the most lenient in their acceptation of results. Colonel Williamson, of the United States Army, who has probably given more intelligent study to the barometer than any other man, has compiled a table of the maximum errors which occur in numerous series of observations taken both in North America and Europe. Among these are many that exceed fifty meters in amount, and he assumes that the barometer under similar circumstances will be liable to equal errors elsewhere. These, however, are not to be considered as representing the probable error of barometrical results, they are rather the extreme limits of probable error, and may be taken as the error to which the barometer is liable under certain rare and very unfavorable conditions. While exact truth concerning altitudes is something which no barometer can be expected to tell, and while it is never safe to guarantee the accuracy of such a determination, even within many meters, yet when barometrical work is prosecuted judiciously and systematically, as it would be in this survey, and based upon formulas which represent the latest and most complete knowledge of meteorology, its tendency is to give results that are seldom more than a few meters wrong.

It is often difficult for the popular mind to comprehend how an error of meters may be inevitable in some of the processes of barometric hypsometry. Since the scale of a barometer may be read to a thousandth of an inch, and that amount of variation is supposed to correspond to a change of one foot in altitude, it would naturally be thought possible to determine the elevation of a place to the nearest foot. But this difficulty will be better understood when it is remembered that the barometrical measurement of the difference of altitude between two places depends upon the determination of the weights of a column of atmosphere at each of these stations;

that this atmosphere is in a state of constant change and perturbation, its pressure being modified by variations of heat and cold, storm and calm, and the absence and presence of moisture throughout different portions of its extent; and that, while some of these conditions are quite unknown to the observer, those that are apparent to him can be but incompletely compensated for. Therefore, since barometric hypsometry is not one of the exact sciences, but is affected by every change in the wind and weather, any determination of altitude that is true within a meter, is as much a source of surprise as of gratification to the meteorologist, who will be obliged to confess that this closeness could scarcely be possible without some coincidence and accidental equilibrium in the disturbing influences to which the barometer is subject.

DIFFICULTIES IN BAROMETRIC HYPSOMETRY.

At times men of little experience may have to be accepted as meteorologists. They work, perhaps, under the embarrassments of exposure, fatigue, and a lack of appreciation of the responsibilities that rest upon them. It may be long before they can be taught to regard those niceties of barometrical work without which it cannot be truly successful; although there is but little hope of determining an altitude to the single foot, yet they have to learn that this is no reason for neglecting that thousandth of an inch which corresponds to a foot. Their instruments may be out of order, owing to the hardships of travel to which they are exposed; the readings may have to be referred to a distant station of very dissimilar physical surroundings; or they may have been taken upon the top of a lofty mountain, in a belt of the atmosphere with meteorological phenomena quite different from those properties of the lower strata of the air, for which our formulas were framed.

These are some of the sources of error which may have conspired to vitiate those results which are fifty meters or more at fault. In Brazil, however, it is hardly necessary to anticipate discrepancies so great as this, since it is a country in which no very great change of altitude is possible, violent and phenomenal storms are not frequent, and the atmosphere is of comparatively steady temperature, and not liable to sudden transitions from one extreme to the other.

BAROMETRIC FORMULAS.

Even if the observations have been made under the most favorable conditions of atmosphere, elevation and location, and are perfect as far as human intelligence can make them so, that is, free from all personal and instrumental errors, there yet remains a consideration which may materially affect the completed altitude. The same observations, reduced by different formulas, will give results in some cases widely different, the discrepancy between the returns of two well-authorized methods of computation frequently amounting to the sum of the real errors of both; this is exemplified in the following determination of the height of Corcovado, in which one system of reduction gives an altitude above the true one, and the other places it too low.

The barometric formula is composed of several terms, each of which is a combination of some physical constants, such as the relative weight of air and mercury, or the variation of gravity with latitude, and some of the barometrical data, as the temperature or moisture of the atmosphere. Of these formulas, there are two general classes, based upon the equations of Laplace and Bessel. Not only do they differ in those constant quantities upon which all barometrical determinations must depend, but also in the presence or absence of an entire term, as the formula of Bessel has a separate factor as a correction for the humidity of the air, while Laplace includes the influence of the aqueous vapor with that of temperature.

Thus it will be seen that the formula of Laplace is more convenient, while that of Bessel is more complete. The scientific world has found it difficult to choose between them, and while Delcros, Guyot, and others have accepted the formula of Laplace, that of Bessel has been adopted by Plantamour, Williamson, and others. But it is admitted, even by those who are in favor of the former method, that the constants in use in Bessel's formula, as modified by the more recent arrangement of Plantamour, are later and more

reliable than those accepted by Laplace, and there is also a prevalent opinion among scientists that some accuracy has been sacrificed to convenience in Laplace's method, a concession which it may sometimes be justifiable to make in the application of a formula, but never in its construction.

The advocates of each system have published examples showing the close accordance of their results with altitudes determined trigonometrically or by spirit-level. But as the number of these remarkable coincidences is about equal on each side, and as in each instance the observations would have given results considerably wrong by the application of the other formula, they prove simply two things; first, that they are coincidences, and that to certain cases the method of Laplace is most applicable, while to others that of Plantamour will yield better returns, and second, that it is quite impossible to devise any formula that will yield an accurate solution of all problems in the barometrical measurement of heights.

Since there seems to be a preponderance of evidence and a growing disposition in favor of Plantamour's formula, it has already been adopted by the Geological Commission as a basis for its barometrical work, and its several terms have been developed into tables for the convenient computation of altitudes. After the preparation of those tables and as a test example with which to prove their efficacy, the height of Corcovado Peak was determined barometrically with the following results:

	Metres.
Altitude of Corcovado, by tables of the commission, based upon Plantamour's formula..................	705.84
By Laplace's formula.................	702.15
Determined by triangulation.........	704.74

	Metres.
Error by Plantamour's formula......	+1.10
" Laplace's "	−2.59
Discrepancy between the two........	3.69

The foregoing is a very creditable and satisfactory barometrical result, and is one more argument in favor of the use of Plantamour's complete formula.

ALTITUDES BY VERTICAL ANGLES.

As a supplement to the barometric hypsometry, every theodolite, whether for meanders or triangulation, is fitted with a vertical circle, from which to read the angles of elevation and depression of those points which are located by intersections, in order to compute the heights of the same. From this angle and the horizontal distance between any two peaks, their apparent difference of altitude is obtained by a trigonometrical calculation, and then a correction is applied for earth's curvature and refraction. In the field these angles are recorded as plus or minus, according as the objective point is above or below the observer's station, whose altitude is invariably determined by barometric readings.

In this manner the heights of hundreds of points throughout the field of survey are found with an accuracy nearly equal to that of the peak from which the angle is taken. Indeed, a mean altitude derived from the three angles of elevation, read from three different triangulation stations, will give the altitude of the point of intersection with less probable error than that of either of the mountains from which it was derived.

METEOROLOGY IN THE SOUTHERN HEMISPHERE.

Brazil stands almost alone as a great civilized country lying in the Southern hemisphere. It is comprehensive in its latitude, reaching from north of the equator far into the south temperate zone. From this unique and favorable position upon the earth's surface, as well as from the liberal patronage bestowed by its government upon the development of science, it needs no prophetic eye to see that this empire is destined to become one of the busiest and most fruitful fields of scientific research. Especially is this the case in the investigation of those great questions concerning the terrestial shape and dimensions, and those others, still more numerous, which from the form of the earth, or from other and unknown causes, vary with geographical position. Important among the latter is the science of meteorology, whose general laws are not the same all the world over, but which are largely influenced by latitude and by proximity to either pole.

The following extract from Colonel Williamson's valuable treatise on the

barometer and its uses, will illustrate the absence and the need of meteorological observations south of the equator:

"It has been determined by actual observations, and confirmed by theory, that the sea-level pressure varies in different latitudes by a definite law, modified in practice by local peculiarities of climate. It has been found that the mean barometric pressure is less in the immediate vicinity of the equator, and it increases towards the north to between latitude 30° and 35° where it is greatest. It then gradually decreases to about latitude 60°, and from there towards the north pole there is a slight increase. In the southern hemisphere, where the observations have been less numerous, the mean pressure seems to increase to between 20° and 30° of south latitude, when it gradually decreases to about 42°, and then commences a remarkable fall, so that towards the south pole, the mean pressure is said to be less than 29 inches."*

In the table of mean heights of the barometer at the sea-level, given in various works on meteorology, there are but two stations south of the equator; these are Rio de Janeiro and the Cape of Good Hope. In north latitude, however, the list comprises more than thirty places at which this determination has been satisfactorily accomplished, by years of observations, and these are favorably situated at intervals between the equator and the pole.

Again, while the horary oscillation in the atmospheric pressure is greatest near the equator, and diminishes thence each way to the poles, the abnormal oscillation is least in regions of small latitude, and increases with the distance from the equator. As the latter is the more incomprehensible and less regular of the two, and consequently the greater source of error, it would appear that, in general, barometrical work would be most reliable in tropical regions, and hence this system of hypsometry would be especially applicable to Brazil. And, in addition to their immediate and practical use in the construction of maps, the meteorological results of a survey of the proposed nature, taken at low and high altitudes, at the sea-coast and in the remote inland, with permanent stations at intervals where long series of observations would be accumulated, would form a basis upon which to establish the general laws of barometric fluctuation throughout this vast portion of the Southern hemisphere.

* 736.6 millimetres.

CONTINGENCIES IN THE SURVEY.

The foregoing are the general divisions and some of the novel features of the geographer's work in the field. While these are sufficient to carry the survey across any ordinary country, certain districts may be encountered in which these methods may not be easily applicable. It is impossible, in a paper of this nature and length, to foresee and provide for all of the emergencies that may arise; it is necessary for the geographer to first see his territory, and then, if he is a true engineer, he will be able to devise some means of survey which will be competent to meet the difficulties, however great they may be.

For instance, it may be asked how a survey based upon triangulation, can be carried across the smooth and unbroken table-lands of a country. The answer will be that the plains are not usually so broad that they cannot be spanned by the length of a triangle-side; and, furthermore, if there are no eminences that can be used for triangulation points, so much less is there need for this system of survey. Over the smooth plain it is possible to travel in straight lines, such being the usual character of roads in a level country, and since a meander by direct routes is reliable, the survey can proceed from one known point to the next with comparative accuracy, tracing in the rivers, lakes, and other geographical features as it goes. As a rough, mountainous country is its own remedy, furnishing a great number of advantageous stations for the survey, so, with the absence of these mountains, vanishes in great part the labors and difficulties of this work.

THE STADIA, OR TELEMETER.

Although the stadia, or *telemeter* process, is too slow for the general prosecution of a geographical survey, there may be occasional areas in which the previous methods will fail, and this will suffice. The direct linear survey of a river, by

this means, has already been mentioned. As another illustration, take the case of a valley—as, for instance, the valley of the Amazon—which is so broken with lakes, swamps, and the many channels and arms of the river, that its islands and shores cannot be reached and located by any means of direct measurement; and where, farther, the vegetation is so abundant and dense, that ordinarily no three fixed points are visible from the water's edge. Here the telemeter may be the only instrument by which the required distances may be obtained. The observer, establishing his instrument in open ground, from which triangulation stations can be seen, sends his assistant, in a boat or otherwise, to such points along the water as may be in sight. These he locates by single observations, reading the distances from the rod held by the assistant. Thus the telemeter station is referred to the observer's position, which, in its turn, can be fixed by means of three-point observations upon the triangulation stations of the bordering cliffs.

In this simple and ingenious way of determining distances by single observations, it is necessary that the diaphragm of the telescope of the observer's instrument should be fitted with two horizontal cross-wires, and that his assistant should be furnished with a graduated rod, or telemeter. Then looking through the telescope, the projection of the cross-wires upon the rod includes a certain amount of the graduation. This is a chord subtending a certain constant angle in the line of collimation, and, by a principle in geometry, this chord increases directly with its distance from the angle which it subtends.

THE PLANE TABLE.

With the use of the plane table, there comes so great a temptation to go into the details of the work, to linger over a small area, and to finish the sheets with a topographical completeness, that its too general adoption will be found to retard the progress of a geographical survey. In addition, it is cumbersome in its shape, offering a broad surface of exposure, and for that reason is not well fitted for service upon high mountain stations, where the wind is strong and storms are frequent. In its favor, however, it must be said that this instrument has been successfully employed upon the extensive geological and geographical surveys under Major J. W. Powell, of the United States, and that very favorable reports have been made concerning its usefulness. The inconvenience of its shape has been modified in this service, the table being composed of slats hinged together, so that it may be folded into a small compass for the purpose of transportation.

When, in the course of a work of this nature, there is encountered a district where the importance of the field will justify a minute and laborious survey, the plane-table will serve an excellent purpose there. It is very useful in the mapping of a populous district, the suburbs of a city, a mining region, or in the representation on large scale of a piece of topography which is interesting as a type of geological structure. It is always an easy matter for the geographer to accommodate himself and his methods to detailed surveys like the above, and it is a mistaken idea to suppose that the exploration of a province, unfits an engineer for the topographical delineation of a parish. In all work of engineering there is a constant tendency towards greater accuracy, refinement, and detail, and it is not freedom which the geographer enjoys, in neglecting the minor features of the earth's surface, but rather a necessary restraint that is imposed upon him, to keep him from sacrificing the important to the unimportant.

THE OFFICE WORK.

As for the computations and other reductions of notes which follow a field season of the survey, there is not space to discuss them here, nor is there any special need of such a discussion, as they do not differ materially from those which apply to geodetic work in general. Nor are the duties of the draughting-room greatly distinguished above the customary routine of such office work. This thing only, may be noticed, that the hand to hand struggle which the field engineer constantly sustains with the forces and obstacles of nature blunts the delicacy of his touch, and makes his hand too heavy for the fine drawing necessary in a map finished for publica-

tion, and there should be in every office a superior draughtsman who is accustomed to the use of no heavier implement than the artist's pen.

This artistic finish is bought by some sacrifice of accuracy, however, and beween the field engineer and the final draughtsman there should be few, if any, middlemen to compile and replot the work, because only the man who has seen the country can reproduce its physical characteristics with truthfulness. In every copy that is subsequently made the face of the land grows more artificial and ideal; each mountain loses its individuality of shape, and assumes a symmetrical regularity which it does not possess in nature; some of the niceties of truthful representation are magnified into exaggeration, and others are overlooked and obliterated; the bed of every cañon grows broader in each successive transcript; and the large hills grow larger as the smaller ones dwindle away. As in a popular parlor game, a whispered story, passing current from mouth to mouth throughout the round of a circle, grows strange and distorted beyond recognition, so in the successive reproductions of a map by strange hands, it loses its photographic truth of execution as the idiosyncracies of the various draughtsmen are wrought into the plan. Finally it comes to represent a country that is unnatural in its regularity, made not so much by the accidents of nature as by the design of man, and moulded by the rules of a uniform and rigid geometry.

PLOTTING THE NOTES.

It is necessary that each engineer shall plot his own notes, as he alone is familiar with their arrangement throughout his books, and only he is able to derive the full benefit from them. Therefore during the office season he will be engaged upon a contour plot of the area which he has surveyed during the preceding half of the year. Here he will collect and compile in graphic shape all of the information which lies scattered throughout the dozen note and sketch-books which represent his labors in the field. Upon this map fine drawing will not be so essential as truthful representation and the utmost accuracy of position that can be attained from the material at hand; an inaccuracy that is barely apparent upon the paper will correspond to a very large error in the field, and so a moment's oversight in the office may invalidate the scrupulous care of a day's or week's work upon the survey.

These sheets will be the basis of all the maps of the survey, no matter in what shape they may be published, and hence the urgency of having them correct in all of their positions, statements and figures, and so complete as to include every detail upon the pages of the sketch-books, down to the shape of a mountain-spur or village, or the presence of a spring of water or dwelling place. As the expense of sustaining an engineer in the field is at least double the cost of his office-work, he should confine himself to what is absolutely necessary in the collection of his notes, and then utilize even the least of these in his subsequent plotting and development of them.

CONTOUR PLOTS.

The plots will be constructed in con tour lines, as that is the only method in which the engineer can give precise expression to his information and impressions concerning the heights, slopes, and forms of the country that he has surveyed. While a map executed in hachures would be more artistic and more pleasing to the eye, it cannot be made so mathematically invariable in its conveyance of ideas, that is, it cannot be made to convey the same ideas to all persons; the bluff that would seem high to one observer would seem low to another, and the depth of shade that would represent a steep gradient to one draughtsman would stand for a moderate declivity to another, according to their peculiarities of judgment, or to the different schools of drawing in which they had been educated. The most skilled cartographer, with one of the best of hachure maps before him, would find it difficult to estimate the angle of any mountain slope, or to tell which of two neighboring peaks was the highest, unless their heights were given in figures.

In a glance at a contour plot, however, he could count the excess of lines in one of these mountains, and so compute its superior altitude; or note the number of lines in a centimeter of space, and so determine the gradient of the earth's

surface there. For this reason the contour plot is the only true basis from which subsequent maps can be made; then, no matter how many field engineers may contribute to this work, their reports will all come to the compiler and final draughtsman, written in the uniform language of lines at regular vertical intervals. Otherwise, if the plots were in hachures, this draughtsman would find it well-nigh impossible to so assimilate them that his finished map would not reveal traces of the many different hands from which it originated.

FINAL MAPS.

Unless the contour lines are so numerous and close together as to produce striking contrasts of light and shade as the slope varies, this map has no meaning to the popular eye. The ordinary observer sees in it only a maze and confusion of lines, of whose design and importance he is ignorant, and so it is of no assistance to him. Therefore, since maps are usually published for the information and guidance of the people at large, it is wise that they should be drawn with hachure shading, which gives a more intelligible but less precise picture of the country. In the construction of this, the contours of the engineer's plot are so many guide-lines to the draughtsman, who graduates the light and darkness of the shade to accord with the divergence or approach of these wavering lines.

In addition to these a map in contours may also be issued for the use of engineers, the projectors of railways, and, more especially, as a basis of the geological and resource charts, to which this system is peculiarly adapted, as its lines of equal level are of great assistance in determining the extent of the various formations, and for depicting those areas of vegetable growth which are bounded by fixed limits of altitude. The dip and strike of a bed of uniform slope being given at any one point of its outcrop, it is an easy matter to trace upon this map its line of reappearance upon the farther side of a mountain-range, or at any other point at which it may be exposed again. Or, by counting the lines of vertical equi-distance, the geologist learns the thickness of the various strata, the extent of a fault, or any other fact in geological dimensions.

REVIEW OF THIS METHOD OF SURVEY.

In this paper the writer is at a disadvantage in appearing to advocate inaccurate methods, and perhaps, at times, actuated by a desire to give a perfectly frank and honest exposé of the subject under discussion, he has magnified the amount of inaccuracy to which the operations described in these pages would be liable; at all events he has been very liberal in his allowance for probable error. Indeed, to those who have been in the habit of reading, and believing, barometrical altitudes that are given down to the tenth of a foot, or sextant determinations to the hundredth of a second, it may appear unpardonably liberal to allow for an error of meters or seconds in these classes of work, and perhaps to some it may seem indicative of professional unfitness in the engineer who would acknowledge the liability of such. But while results like the above are frequently published, their authors would be either sciolists or charlatans if they were to claim that they were absolutely reliable down to those small fractions; it is often the custom among the most conscientious and intelligent engineers to make their reports in that elaborated form, since those are the figures at which their computations finally arrived, and hence there are certain weights of probability in their favor.

In like manner, in the computations of a survey of the proposed nature, it would never be allowable to neglect or throw away any odd figure or fraction, on the plea that it was probably exceeded by the error of the whole. By following this system, not only are habits of accuracy inculcated and sustained among the assistants of a survey, but the closest possible approximation to the truth is attained.

In the ordinary branches of his profession, habits of rigid precision, at whatever cost of time and money, are the best recommendations for an engineer. In a geographical survey, however, to enforce this rule beyond the triangulation, upon which the integrity of the whole depends, and to continue it in full force throughout all of the subordinate

branches of the work, would be to make such a survey impossible in Brazil, owing to the enormous expense that would attend it. Viewed theoretically, the best of maps, even those produced by the tedious processes of the European topographical surveys, are but approximations to the truth; the question now arises as to how close it is profitable to bring this approximation. Viewed practically, the maps that would result from the proposed system of survey would be seldom, if ever, in error to a perceptible degree, and it would seem that this is the limit of accuracy beyond which this country cannot well afford to go.

To condemn a method of surveying because it is not absolutely accurate would be to condemn all of the survey of the world, and especially all of the systems of ordinary land surveying, which are so faulty that it is very seldom that a purchaser of land does not get either considerably more or less than he pays for. Still, that has not been deemed sufficient reason why all buying and selling of real estate should cease until its boundaries could be determined by the instrumentality of such rods, compensated for temperature or packed in ice, as are used in the measurement of geodetic base-lines. In one respect the proposed system is far superior to the land survey, as it is founded upon the principle of triangulation, which, securing it in its true proportions, prevents any great accumulation of error. In the United States of North America, where surveys of this nature are in active and successful operation, it has been earnestly advocated that the triangulation of the geographical survey should be made the basis of the land survey, the different triangulation stations serving as initial points from which to run the land boundaries, and it is very probable that, within a year or two, this plan will be adopted there.

There are different degrees of accuracy, each adapted to the end which it is intended to serve; this degree, explained here, is sufficient for the rapid preparation of a very useful and complete geographical map. It would not suffice for the measurement of an arc of the meridian, such as has been proposed for this empire. That is a work in which no error, however small, that is not beyond the cognizance of the human senses and judgment, can be excused or overlooked. To publish a wrong result here would be not only a national disgrace, but a misfortune to the whole world, as it is upon the shape and dimensions of the earth that many of our geodetic and other scientific formulas rest, while it is from the same source that the world derives its standard unit of length, by which the interests of all civilized people are affected. Or, if Brazil were prepared to enter into that honorable rivalry in geodetic work, in which some of the older nations are engaged, each seeking to produce instruments, methods, results, discoveries, and developments that may be in advance of everything hitherto achieved, this system of survey would not be recommended. It is not impossible, however, that, from this as a beginning, there might grow, keeping pace with the general progress of the country, a geodetic institution that would be equal to the best.

ORIGIN OF THIS SYSTEM.

The writer by no means pretends to be the inventor of the combination of methods described in these pages, although hitherto there has been but little description of them in print. An efficient system of survey cannot be the invention of any one man; it must be the outgrowth of years of practical experience, resulting in the gradual accumulation of ideas and improvements contributed by those who have been engaged upon it. This one is the result of a growth of at least a quarter of a century, and therefore is not open to the serious objection of being new and untried. During that length of time, the enterprise of geographical surveying has been receiving more and more encouragement from the government of the United States, which has wisely adopted that plan, in connection with geological and other scientific research, as a means of opening and illustrating its vast public territory.

At the present day there are actively engaged upon this duty in that country three important commissions of survey. That of Dr. F. V. Hayden, geologist in charge, is known throughout the world by its extensive and important work, not

only in geology and geography, but in all their kindred sciences as well. A second is under Major J. W. Powell, the intelligent geologist and intrepid explorer who was the first to descend the great cañon of the Colorado River. Another, more strictly geographical in its nature, is under the auspices of the War Department, and is conducted by Lieut. George M. Wheeler, an officer of enviable reputation in the United States Corps of Engineers. While the general plan is much the same throughout these three commissions, it is especially to his former associates, the geographers and officers of the last-named organization, that the writer wishes to acknowledge his indebtedness for whatsoever of value there may be in this paper.

BRAZIL AND THE UNITED STATES.

Although, as has been stated heretofore, it is not wise for any nation to copy, blindly, and without adaptation to its own peculiar needs, the system of survey employed by any other country, yet it would seem that the processes that are fitted to the United States would require but little modification to be adapted to use in Brazil, so analogous are the two countries in many respects. They have equal amounts of territory as near as may be, but, peopling this territory, there are four times as many inhabitants in the United States as there are in Brazil; thus it would seem that the methods that are deemed sufficient for the former would certainly suffice for the latter. In each country the population diminishes from a thickly-settled seacoast back into an uncivilized and almost unknown interior. In each of these there is a great amount of wild land which the government is anxious to open to colonization and cultivation. To expose and popularize the natural wealth of this public domain, the U. S. Government resorted to the plan of scientific surveys, to which the Geological Commission of Brazil is very similar in all respects, and so efficiently have they accomplished their purpose that it has become a noticeable fact in the cartography of the United States that its maps of some of the remote and unsettled districts of the Rocky Mountains are superior to those of its oldest and richest States, and, therefore, there are now plans on foot looking to the extension of these geographical surveys over the entire surface of the country.

As the American manner of railway-building, more expeditious and involving less first cost than the European methods, has been found practicable in Brazil, in some instances, in which all other plans would fail, so with this question of geographical surveys, it may prove to be the American system or none.

RESULTS OF THIS SYSTEM.

Considering now the results that could be expected from such a geographical survey of Brazil, this question can be best answered by referring to areas surveyed in the same manner in the United States. From Lieut. Wheeler's annual report, which the writer has before him, it appears that in six years' continuance of his commission an approximate extent of 800,000 square kilometers has been surveyed. Allowing an average of five parties in the field during that time, the season's work of one engineer reduces itself to about 25,000 square kilometers. Allowing proportional returns from the various other geographical surveys at present in commission, or that have been in existence during the last ten years in the western portion of the United States, it appears that one-third of the area of that great country has been thus surveyed in that period.

This is at a total expenditure which, while including the cost of all other concomitant scientific labors, to which the geographical work has been in large part incidental and tributary, has never exceeded four hundred contos ($ 200,000) per year. There is probably no other department of public enterprise which has yielded so extensive and valuable returns for an equal amount of money.

AN ESTIMATE FOR ONE SEASON.

In general, an area of from 10,000 to 30,000 square kilometers, varying according to the geographical nature of the country, is assigned to each party for a season of four, five, or six months, and its ability to satisfactorily cover that district in that time is conceded. To illustrate the possibility of such rapid progress, let us take a typical area of 20,000 square kilometers and see what can be done with it by one party and

one geographer in one season's work of six months in duration. Of this time the first month will be consumed in the measurement and development of the base, and in other preparation. Of the remaining period one month more will perhaps be lost in unavoidable delays resulting from storms or other causes. There will then remain four months, which, at twenty-five available days in each, will afford one hundred days for active service in the field.

Allow one half of these days for the meander survey, and the other half for the occupation of mountain stations. Fifty mountain stations will thus result, and, in addition to these, there will be a topographical station either upon or adjacent to each day's meander. So there are one hundred triangulation and topographical stations distributed at judicious intervals over this territory. That is, there is one for every two hundred square kilometers of ground, or, typically, they are but about fourteen kilometers apart, and the piece of country to be sketched in contours need not extend more than seven kilometers in each direction; this estimate ignores the meander surveys, to which fifty days of the season will be devoted, and by which these stations will be separated and surrounded.

At twenty-five kilometres a day, a very reasonable allowance, the total distance of meander route will be 1250 kilometres. This distance would reach across our area nine times, cutting it into strips of sixteen kilometres in width. Hence, in order to include the entire country from this survey, the typical zone of each meander would not reach more than eight kilometres on either side of its path; but, since it would be superfluous to sketch from this base the country in the immediate vicinity of the mountain stations, these plots *en route* need never extend more than four kilometres from the central line. Of course, in practice, these surveys will not be thus distributed in straight lines at equal distances apart, but will communicate, intersect, and duplicate in every possible way. Still the meander will serve its original purpose of penetrating those regions and traversing those border-lands that are remote from the mountain stations, and will trace out the roads, trails, and important streams, whose entire length in this area will not be likely to exceed 1250 kilometres.

Returning to the office at the end of the season, the engineer will have material enough to make a plot of the country on a scale of one centimetre to the kilometre ($\frac{1}{100\,000}$), or one-half a centimetre to the kilometre ($\frac{1}{200\,000}$). Or, to put this statement with more precision, he will have so much and so detailed material, that he will not be able to portray it conveniently and intelligibly on a scale of less than $\frac{1}{200\,000}$. But when the final draughtsman comes to copy these plots, he may condense them, if it be thought expedient, to proportions of $\frac{1}{400\,000}$, or even smaller. On the other hand, portions of this area may be plotted upon a much larger plan than any here noticed, should such be found necessary for the clear and complete geographical and geological representation of the same.

EUROPEAN SURVEYS.

Now in contradistinction to the above showing, let us take up the reports of some European surveys. In Prussia, 12,000 square kilometers, a little more or less, are surveyed annually, at a cost of 800,000 marks, or, as near as may be, four hundred contos of Brazilian money,* exclusive of the salaries of military assistants; notice that in the United States, with a total annual appropriation not greater than this, at least 300,000 square kilometers are geographically surveyed each year, this territory being studied at the same time by the geologist, the chemist and the naturalist.

Upon the Ordnance Survey of Great Britain there were over 1800 assistants and employés engaged during the year of 1874; the total area surveyed by them was not more than 8,000 square kilometers. With the methods in use in Austria an experienced topographer can survey in one field season of six months five hundred square kilometers at the farthest. In Switzerland the topography is in large part done by contract, and it alone, exclusive of triangulation and publication, costs 700 or 800 francs per square stunde, or about twenty-two mil reis† per square

* A conto of reis, in Brazil, is equal to about five hundred American dollars, or a hundred pounds sterling.
† Eleven American dollars.

kilometer. So with the surveys of Italy, Spain, Sweden, and the other European countries of comparatively small extent; they are so slow, detailed, and withal so expensive as to be inapplicable to the great empire of Brazil.

AN ADVANTAGEOUS DEVELOPMENT.

So vast is the extent of this empire that the idea of a geographical survey of its territory, as a whole, is an astounding one, and is liable, in itself, to forbid all further consideration of the subject. But this plan does not necessarily imply the regular extension of this survey over the whole country, irrespective of population and wealth. On the contrary it would devote itself at first to such areas as, from geological or other economical reasons, might most urgently require it, and a region of especial interest to the geologist would be surveyed first and with especial care, to the neglect or even exclusion of those great stretches of country whose structure is unvaried and monotonous. In a few conditions of its plan, as, for instance, in the system adopted in the projection of its maps, it might provide for any possible ultimate extension, but in other respects it could operate with equal facility, in whatever districts might be assigned to it.

Nor does this plan imply the necessity of any great outlay at the beginning, but would ask to start upon a small scale at first, with a view to gradual growth as it proved itself worthy of encouragement. As the aim of this project would be not only the production of much-needed maps, but also the introduction of these methods of survey from abroad, and the training of Brazilian engineers in the use of the same, any very extensive initial basis would prove not only embarrassing at first but also probably disastrous in the end. A survey inaugurated upon a grandiose scale is too liable to exhaust the patience and liberality of its official patrons before it can exhibit results apparently equivalent to the expenditure that it has caused, and the frequent fate of such enterprises is that they are discontinued at about the time when, their organization being successfully completed, they are prepared to enter upon an area of efficient and fruitful labor; hence, all of the expense of organization and other preliminaries becomes a total loss to the government.

On the other hand, some of the most important surveys of the world have arisen from humble beginnings. Such an enterprise educates its own members, the assistant engineer of one season becoming the engineer of the next, and so on. It develops gradually and with a healthy growth, perfecting its own methods, and always experimenting upon a small scale, so that it is never liable to serious disaster. And, above all, by its early production and exhibition of results commensurate with its size, and with its cost, which is insignificant at first, it buys the right to be continued, encouraged and increased from year to year.

A GEOLOGICAL AND GEOGRAPHICAL SURVEY.

There are two very good arguments for such a geographical survey in connection with the Geological Commission of Brazil; first, its necessity to the geological survey, as explained in the early part of this paper; and second, because in such a connection it can work most economically and profitably. With a combination of these elements comes much valuable co-operation between the representatives of the various branches of science, and this is constantly acting to lessen the expense and increase the returns of such a survey. For instance, as the meteorologist of the engineering corps, an assistant with some acquaintance with geology, could be chosen. As his meteorological duties upon the march would be but light, he could devote much of his time to a geological study of the road, leaving the regular geologist at liberty to go from camp to camp by any other route that he might select. Again, the meteorologist, or even the engineer himself, may make stratigraphical sketches upon every mountain, and bring specimens of rock from the same, while the geologist is away upon some detour to regions of interest in another direction.

Or, reversing this illustration, the geologist, whose profession is so closely allied to that of the geographer, is constantly making notes of direction, distance, slope, and altitude, which are of the highest importance and use in the

construction of a map. These are lost to the world if there is not an accompanying geographical survey into whose plots they may be assimilated.

In witness of the sympathy with which the present members of the Geological Commission regard geographical work, and of their skill in the prosecution of the same, the writer would mention their intelligent and extensive surveys of the valley of the Amazon, from Monte Alegre westwards, and of its tributary, the Trombetas; of the island of Fernando de Noronha; and of many localities along the Atlantic coast and elsewhere in the empire. These are evidences of a willingness and an ability to collect geographical information, which, in themselves, assure the success of a system of geographical surveying in connection with the Geological Commission of Brazil.

ON THE PRESENT AND FUTURE WORK OF ENGINEERS IN REFERENCE TO PUBLIC HEALTH.*

By Mr. W. DONALDSON, M. A.

From "The Builder."

INTERMITTENT downward filtration by irrigation over wide areas affords the only means of readily overcoming all the difficulties of sewage purification. Purification by continuous drenching of the land, generally called intermittent downward filtration, cannot be successfully carried out without the use of settling-tanks; that is, not without the necessity of piling up heaps of sewage sludge which has very little manurial value. The getting rid of this sludge must, therefore, entail a yearly loss. It is true that on many, probably on the majority of irrigation farms where utilization and purification are combined, these tanks are used for the clarification of the sewage before it is turned on to the land, but there is, however, not the least necessity for their use. If the sewage is kept in motion, the fine sediment is deposited evenly over the surface of the land during the process of flowing, and does not leave any visible indications of its presence, if there is an adequate area of land under irrigation. It is, of course, necessary to separate all solid bodies from the sewage by means of screens, but the total of these screenings is very small. At Reading, including the deposit of heavy sand in the screening tanks, the average daily quantity does not exceed three-quarters of a cubic foot per thousand, but at Reading the duplicate system is strictly carried out, and the sanitary authority has not to deal with the road grit nuisance.

Colonel Jones has adopted these settling-tanks on the Havod-y-Wern Farm, and is now engaged experimenting on the sewage sludge with the hopes of making it salable at a profit. He may possibly find a profitable market for the small quantity deposited in the tanks at Wrexham, but his success will only be partial. Until manure made from sludge can be sold at a price which will admit of carriage to a long distance, the use of settling-tanks must entail a yearly loss.

In my opinion, the want of success on irrigation farms has been in no inconsiderable degree owing to the half-hearted way in which the advocates of utilization have taken up the question. They ought to have regarded purification as quite a secondary consideration, because utilization must necessarily accomplish successful purification. The problem which they have hitherto attempted to solve has still been, how few acres will effectually purify the sewage of 1,000 people? The exact converse ought to have engaged the whole of their attention, how many acres will the sewage of 1,000 people effectually fertilize. The nuisances occasionally experienced on sewage farms, which are the main cause of the difficulty of acquiring land, need never occur except in those cases in which the minimum standard of acreage requisite for purification has been adopted.

* Abstract of an Address before the Sanitary Institute.

Sir Joseph Bazalgette at the discussion by the Sanitary Institute in March, 1877, upon the mode of treating town sewage, arguing from the example of London, came to the conclusion that it would not be possible to obtain land in the neighborhood of large towns in sufficient quantity and suitable quality and free from residences, for the purpose of sewage farming. He comes to this conclusion because London with a population of 4,000,000 would require an area of sixty square miles, which, expressed in another way, is an area less than eight miles square. London is, however, about ten times larger than any other town in the kingdom, so that arguments against the adoption of irrigation derived from the example of London, even if well founded, are not applicable to any other case. In my opinion, however, the argument is not in any other respect well founded. Surely in a food-importing country like England, the more acres the sewage manure will not only fertilize, but render at least doubly more productive than they can be made by any other manure, the better for the people. It is not necessary that the area required for irrigation should be either in the immediate neighborhood of the town from which the sewage has been sent, or free from residences. If a sufficient area is used, no nuisance will be occasioned, and sentimental fears on that head can easily be allayed by interposing a belt of unirrigated land.

If the Town Council of Manchester can bring water from Thirlmere to Lancashire and sell it at a profit, it is clear that sewage may be conveyed to an equal distance and also sold at a profit, if its commercial value is equal to that of the water. For the purpose of comparing the values of the two commodities we must not adopt as the standard of the value of the water the price at which it is sold, after having been distributed throughout the district to each set of premises, but what it is worth in the service reservoirs. In order to ascertain its value in the service reservoirs we must deduct the cost of distribution, which includes nearly all the cost of management and maintenance, not from the price at which it is sold for household purposes, but from that at which it is sold in large quantities for commercial purposes, because Waterworks Companies do not sell any water at a loss. Taking all these points into consideration we cannot assign a higher value than 2d. per thousand gallons to the water in the service reservoirs previously to distribution.

In the Reports of the Rivers Pollution Commissioners the manurial value of sewage is said to vary from a maximum of 2d. per ton in dry weather to a minimum of ½d. when the sewage is diluted with storm water. According to these estimates the value of crude sewage varies from 2½d. to 9d. per thousand gallons.

I am well aware that you will not regard the theoretical estimates of analytical chemists as evidence of much value in support of my views as to the actual value of dry weather sewage, because it is the general opinion that this value can never be realized. I shall therefore endeavor to show you that this view of the question is erroneous, that in reality the smallest value is in all cases actually realized by the production of magnificent crops, and that the failure takes place in the next stage. The full value of the crops is not realized. Irrigation farms in the hands of practical farmers, who understand the art of making the most of the farm produce, cannot fail to pay handsome returns in hard cash, but practical farmers keep their balance-sheets to themselves.

On the basis that the sewage of 100 people can properly fertilize only one acre, and at the rate of twenty gallons per head of sewage, which is a high estimate where the separate system is in force, one acre will acquire annually 730,000 gallons. We have now to consider what that acre of land under sewage irrigation is capable of producing. One acre sown with rye grass will produce five or six crops a year,—fully sixty tons of grass. This is sold at prices varying from 10s. to 20s. according to the demand and the locality of the farm. Estimated at only 10s. per ton the gross return would be about £30 per acre. From corn and root crops the gross return is worth from £20 to £30 per acre. Against this amount is to be debited rent, taxes, working expenses, and interest on farm capital. If the land is let at an ordinary agricultural rent, £12

a year ought to cover all the yearly charges under these heads, and a balance of from £12 to £14 per acre would be left to divide into tenant's profits and payment for the sewage as a manure. If this be divided equally between them the amount paid for the sewage would be over 2d. per thousand gallons. If £3 a year per acre in addition to interest on sunk capital be considered a fair tenant's profit, the value of the sewage would on that basis be more than 3d. per thousand gallons.

In Colonel Jones's pamphlet on the Havod-y-Wern Farm it is stated that the average net profit for five successive years amounted to £3 4s. 4d. per acre. The rent paid by Colonel Jones is nearly £5 per acre, so that the rates and taxes must be proportionately heavy. As he is only tenant, he puts on the debit side a yearly sinking-fund, to recoup himself for capital sunk in permanent improvements, which amounts to about 7s. per acre; with this addition the total net profit made by Colonel Jones is about £3 11s. per acre. This, however, represents only part of the whole profit. The cows fed on the farm are owned and kept by another man, who is presumed to live on his profits, but publishes no accounts. There are only ninety-two acres, so that the profit made by the cow-keeper cannot well be less than 30s. an acre. If the rent paid by Colonel Jones had been an ordinary agricultural rent, his profits would have been increased by a deduction of fully £3 10s. from the debit side in the amount charged for rents, rates and taxes. Making these allowances, the total net profit made on the Havod-y-Wern Farm has been, on an average of five years, fully £8 per acre.

The successful disposal of sewage crops is at the very root of the whole matter. To state that there is a difficulty in finding a market for them in some cases is tantamount to saying that there is no home demand for milk, butter, cheese and beef. The produce must be consumed on the farm and converted into food for man before it is brought into the market. This work can only be successfully carried out by private enterprize. So far, therefore, as the interest of Sanitary Authorities are concerned, the only point to be considered is the question of the rent at which they will be able to let irrigated land.

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers.—The annual convention of this society was held at Boston, beginning the 18th of June and adjourning on the 22d. The discussions and the excursions to neighboring localities were carried out in accordance with the programme.

The last number of the "Transactions" contains the following papers:

156. On a new method of detecting overstrain in Iron and other metals, and, on its application in the investigation of the causes of accidents to bridges and other constructions. By Prof. R. H. Thurston.

157. Steam Engine Economy. A uniform basis for comparison. By Chas. E. Emery.

158. The Inclined Plane Railroad at Madison, Ind. Its history and operation. By M. J. Becker.

IRON AND STEEL NOTES.

Steel *v.* Iron.—There is nothing in which modern progress is better exemplified than in the manufacture of steel for all purposes for which iron was formerly used. Thanks to the inventions of Bessemer and Siemens, we have arrived at the stage, where best quality steel rails, in some cases guaranteed to remain sound during a wear of ten years, are sold at prices very little higher than ordinary iron rails. A similar result is likely to follow with respect to the plates used for boilers and shipbuilding. Steel is now produced by the Bessemer and the Siemens-Martin processes, which with a tensile strength one fourth greater than iron, gives such superiority in elongation, reduction of area at point of fracture, bending, flanging and twisting, as have not been even approximately approached by the very best Yorkshire iron at considerably higher prices. We have seen specimens, showing results which might have been expected of copper, but not of iron or steel. We are surprised at hearing that the world-renowned best Yorkshire iron seems destined to be superseded by this mild steel in the same way as steel rails have taken the place of the iron ones.

We have obtained from Messrs. John Brown and Company (Limited), some interesting information on the subject of the manufacture and the capabilities of this material manufactured at their works by the Bessemer process, and the systematic care taken in the different stages. Each heat is tested chemically and mechanically, and each plate is also tested before being sent out, thus insuring that uniformity which is so much to be desired, and preventing the possibility of any unsuitable material being supplied. For this class of steel only the best and purest pig-irons are used in the proportions which long experience and the continually repeated analyses show to be most suitable. As soon as the operation of conversion is completed, and the preliminary bending-test and the analysis of the steel show that

it is of the desired "dead-soft" temper, an ingot is hammered and rolled into plates, which are annealed and then subjected to tensile, bending and welding tests. For the tensile test, strips planed out of the plates are placed in a lever-testing machine specially constructed for this purpose, and the load is increased until the pieces are torn asunder. The strain at the point of fracture should be between twenty-six and thirty tons per square inch. If found higher than this last-named strain, the heat is not used for boiler plates. In steel within the above limits of tensile strength, the test piece, eight inches long, will be found to have stretched at least twenty per cent. before breaking, and its sectional area at the point of fracture reduced about fifty per cent.; showing very great ductility as well as great strength. For the bending test similar strips are heated to a cherry-red heat, and quenched in cold water until quite cold, and then bent over close. This they must do without signs of fracture. Other strips are heated to a welding heat and lap-welded in the same way as iron is welded, the square ends of the strips not being in any way prepared for welding. On the sample ingot satisfying all these tests, the whole heat, varying from eight to ten tons, is used for boiler plates, which may be required to weld. If only the two first tests are satisfied—which is sometimes the case—the steel is used for ship-plates or shell plates of boilers, where it is not required to weld. When the plates have been sheared to the size ordered, they are annealed, that is to say, put into a heating furnace heated slowly and uniformly and allowed to cool slowly. A strip cut off every plate is subjected to the quenching test above described, and being stamped with the corresponding consecutive number of the plate, a record is kept of its quality before being sent out. Should any one of the tests not be fully up to the standard, the plates to which they belong are rejected. Thus the quality of each plate sent out is known and approved, and the fact of the plates being sent is an assurance to the consumer that the quality has been fully ascertained to be suitable for the purpose required. We understand there has been a prejudice against steel for boilers, owing to the want of uniformity which existed in years gone by, but this uniformity is now completely obtained. In answer to our inquiries if any difference of treatment is necessary in the use of this steel in place of iron, we are informed that, like all steel, it should not be heated as much as iron for flanging and welding, and that after recent careful experiments, Lloyd's surveyors have arrived at the conclusion that plates up to ½-inch thickness inclusive may be punched without more damage to the material than is caused by punching iron plates, but that plates above ½ inch thick should be drilled, or, if punched, afterwards rimed at least ⅛-inch, or annealed. Either of these operations will leave the material at the original strength per square inch of sectional area, and it is therefore recommended to treat all plates below ½-inch thick when possible, as well as thicker plates, in one of the three ways described. It is also recommended that all plates which have been flanged should be annealed to restore the material to a state of rest, as the annealing will effectually remove the various and considerable strains set up by the present method of flanging the plates—by heating the plates locally first in one place and then another for flanging.

Among the samples illustrating the preceding remarks, shown us by John Brown and Co., are some very extraordinary ones. One is a ⅜-inch steel plate dished cold, the inside diameter being 10 inches, and depth, 5¾ inches. A similar plate was bent five times upon itself without a crack. Another plate was punched with sixty-one holes of ⅝ inches diameter, with only ¼-inch spaces, showing very little distress to the metal. Ordinary twists and bends are hardly worth quoting, but a ½-inch square bar subjected to six complete twists without a crack is so exceptional a test that it must be mentioned. These, however, are *tours de force.* A practical fact in the same direction is that steel angles, 9 inches by 4 inches by ½ inch, are rolled in forty feet lengths for Midland Railway coaches, and that beater-bars for thrashing machines are rolled in great numbers for Messrs. Garrett, and other eminent makers, and every satisfaction is given by the material. —*Iron.*

RAILWAY NOTES.

NEW TRANSPORTATION CAR.—The Ashbury Railway Carriage and Iron Company, Openshaw, have constructed a novel kind of railway wagon, specially adapted for conveying dead meat, fish, fruit, or other perishable goods. The vehicle, which externally resembles an ordinary wagon, is built with double walls, and the intervening space is filled with layers of non-conducting substances—namely, sawdust and paper. The whole of the interior is lined with galvanized zinc, which also composes the bars and hooks upon which the meat, &c., would be hung. Along the roof runs a semicircular chamber capable of holding twelve cwt. or fourteen cwt. of ice, and into this chamber the air is first introduced, after the freight has been deposited in the van and the door hermetically sealed. After passing through the ice, the air is forced through a receptacle filled with charcoal, which dries it, and then circulates among the contents of the wagon. It is afterwards discharged through an automatic discharge pipe. This is the first wagon of the kind built for any English railway, and it is intended for service between Scotland and London. With this contrivance meat can be kept perfectly fresh for five or six days, and in case of the market being overstocked the meat may be kept in the van, which is thus converted into a temporary storehouse. The arrangements for cooling and drying the air have been designed by Colonel W. D. Mann, of the United States army, who has had considerable experience upon the railways of America and the Continent.

CHEAPEST RAILWAY IN THE WORLD.—The cheapest railway in the world is to be

found in the peninsula of East Frisia, in the extreme north-west of Germany. The peninsula has the thinnest population anywhere to be found in central Europe, and the soil is almost completely moor. A railway was, some years ago, built with Government assistance, connecting Bremen and Oldenburg with the town of Emden; but this line had to be laid down absolutely straight, to save expenses. This left the village of Westerstead five miles from its track, to the distress of the inhabitants, who tried to persuade the Government to deviate from the straight line. When they found that all petitioning was useless, they determined to make a railway of their own. It appeared almost impossible to construct a line that would pay its expenses, among a population of ten inhabitants per square mile, wholly agricultural, exporting nothing but cattle, pigs, and the scanty produce of the soil, and importing little else but a few articles required for domestic consumption. But the parish of Westerstede may now, says the *Railway News*, boast, probably beyond challenge, of possessing and maintaining the cheapest railway in the world. The line, which is a single one throughout, is about five miles long, running from the hamlet of Ocholt, and to the village of Westerstede, the terminus here being the yard of the principal inn. It has a gauge of 2 feet 5½ inches, and the rails, made of Bessemer steel, and weighing twenty-five pounds to the yard, are of the Vignoles shape, connected by fish-plates only, so that they rest directly on the sleepers. Although the country is perfectly level, consisting principally of moorland and heath, the earthworks were not altogether unimportant, as considerable drainage works had to be carried out to protect the railway from occasional floods, to which the whole of East Friesland is liable, since it rises but little above the level of the North Sea. The line has its own earthworks, but runs for some distance close alongside the ordinary road, separated from it by a ditch and a quickset hedge. There is but one station on the line, half-way between Ocholt and Westerstede; but, strictly speaking, this is no station at all, but merely a halting place for the trains. A forester's cottage stands here, the owner of which allows intending passengers to sit down in his room and await the arrival of the trains. The rolling-stock consists of two small tender-locomotives, three passenger carriages, two closed goods vans, and four open trucks. The locomotives, four-wheeled, with a wheel base of 5 feet, and a heating surface of 172 square feet, weigh seven and a-half tons when loaded with fuel and water; they only burn peat, abundant in the district, and have, instead of a whistle, a bell, which is rung at every level crossing. The passenger carriages each hold twenty-eight passengers, sitting omnibus fashion, with a door at each end, which arrangement is necessary as the trains cannot turn, there being no turntable on the line. The working staff consists of four persons, an engine driver, a fireman, a guard, and a plate-layer, their total wages not amounting to more than 13s. a-day. The entire working expenses are returned as exactly £1 9s. per diem, the items of expenditure being, besides wages, 6s. for peat-fuel, and 10s. for maintenance of permanent way, repairs, grease, and other indispensable matters. There are no buildings on the line, except a rough shed for the cover of engines and carriages at each end; nor are there any signals. The passenger fares, which are low, being 6d. first-class 4d. second-class, are collected by the guard. He also accompanies the goods trains, collecting the charges, which are 1s. for a beast, 3d. for sheep and pigs, and at the rate of 2s. per ton for general goods. Pigs are the chief article of export of the district. The company, composed entirely of inhabitants of the district, including agricultural laborers, raised a total capital of £11,200, and of this only £10,450 were disbursed in the building of the line, purchase of rolling-stock, and erection of sheds, leaving a surplus of £750, which sum was placed aside as a reserve fund. To aid in starting the undertaking, the parish of Westerstede, by vote of the communal representatives, subscribed £1500 as a gift, to be returned only in case of the repayment of the whole of the debenture capital. From the returns as yet published, it appears that, in the first seven months during which the line was open for traffic, the gross receipts came to an average of £2 8s. per diem, so that, with working expenses of £1 9s., the net earnings were at the rate of 19s. a-day.

ENGINEERING STRUCTURES.

A Great Engineering Feat.—The new railway bridge over the river Tay was opened with much ceremony on the 31st May. The first movement to bridge the Tay was made about forty years ago by the Edinburgh and Northern (afterwards the Edinburgh, Perth & Dundee) Company. It was not till 1871, however, that a project destined to be fulfilled was initiated. In 1870 the necessary Act of Parliament was obtained, and on the 8th of May of the following year the contract for the erection was signed. The contract was transferred in 1873 to Messrs. Hopkins, Gilkes & Co., of Middlesborough; and Mr. A. Grothe, who was engineer and manager to Mr. De Bergue, and had shown very great professional skill in the manner in which he proceeded to erect so gigantic a structure was continued by the new contractors, and the admirable, thoroughly substantial bridge which now spans the river is a proof of their wisdom in taking Mr. Grothe into their service. The bridge is 10,612 feet in length—or two miles and fifty-two feet —and is thus the longest railway bridge over a running stream in the world. The Victoria bridge, Montreal, comes next in respect to length, being 9194 feet, or 1418 feet shorter than the Tay bridge. A still more extraordinary bridge than either is one on the Mobile and Montgomery Railroad, called the Texas and Mobile bridge, which is fifteen miles in length; but as the greater part of it is carried over immense morasses, it cannot be fairly compared with the Tay bridge, which spans a tidal river. The bridge starts from the Fife

side of the Tay, where the land is about seventy feet above high water, and gradually rises at a gradient of 1 in 356 until the highest part of the bridge is reached, being 130 feet from the level of the rails to high-water mark. The greatest altitude occurs at the center of the large spans, and from this point towards the north side there is a sharply falling gradient of 1 in 74. In the structure there are eighty-five spans of the following dimensions: eleven spans of 245 feet each, two spans of 227 feet each, one span of 166 feet, one span of 162 feet 10 inches, thirteen spans of 145 feet each, ten spans of 120 feet 3 inches each, eleven spans of 129 feet each, two spans of 87 feet each, twenty-four spans of 67 feet 6 inches each, three spans of 67 feet each, one span of 66 feet 8 inches, six spans of 28 feet 11 inches each. All the spans, with the exception of that of 166 feet, which is made by a bowstring girder, are formed of lattice girders, but in addition to these spans, there are adjoining the north end of the bridge: one span of 100 feet, bowstring girders; one span of 29 feet, plate girders. The thirteen largest girders, each being about 200 tons in weight, are in the center of the bridge, and over the navigable part of the river. The girders are arranged in continuous groups, with proper provision for expansion, and are all supported on piers of varied construction. The permanent way consists of double-headed steel rails, fished at the joints in twenty-four feet-lengths, weighing seventy five lbs. to the yard, and secured by oak keys in cast-iron chains. The chains are fixed at intervals of about three feet to longitudinal timbers seventeen inches wide, and varying in depth from seven to fourteen inches. Throughout the whole length of the bridge each rail is provided with a guard-rail to afford additional security to trains passing over the structure. The floor of the bridge consists of 3-inch planking, and is covered with a waterproof composition. On both sides of the bridge, for its whole length, a strong handrail is erected, and painted in a light blue color. The foundations of the piers are formed of iron cylinders, with brickwork and cement. Fourteen piers at the south side are built entirely of brick, and on rock foundation, and consist of two cylinders of nine feet six inches in diameter, connected by a wall of brickwork three feet in width. At the fourteenth pier it was found that the rock suddenly shelved away to a great depth, under beds of clay, gravel, and sand, and therefore another kind of pier had to be resorted to which would give an equally sure footing. The weight of the pier was lighted by substituting for the heavy brickwork above high water cast-iron columns, fixed together by horizontal and diagonal transverse bracing, and the cylinders were increased to fifteen feet in diameter. The whole of the piers after the fourteenth are built in this manner, but in the case of the highest pairs, supporting the 245 feet spans, they have a cylindrical base of iron and brick in cement thirty-one feet in diameter, and from forty to forty-five feet in depth, standing a few feet above high water. The whole of the cylinders supporting iron columns are finished with a coping of Carmyllie stone. The first stone was laid on the Fifeshire side on the 22nd July, 1871, and on September 25th, 1877, six years afterwards, the directors and engineers had the satisfaction of crossing over the bridge for the first time in a train. The contract price of the bridge was £217,000, but the actual cost is £350,000, the great increase being caused because of the original plans of the piers having to be departed from, and plans prepared of another description of piers adapted to the soil in the bottom of the river. The quantities of materials used in the structure are as follows:—3520 tons of cast iron, 6281 tons of malleable iron, 90,600 cubic feet of timber, 8600 of cement, 4,350,000 bricks, 27,000 cubic feet of dressed ashlar, and 355 cubic yards of rough ashlar. The engineers engaged in the construction of the bridge were: Messrs. Alfred Grothe (superintending engineer) Frederick W. Reeves, G. G. Lawrence, R. S. Jones, Theodore D. Delprat, G. D. Delprat, and Thomas Templeton. On Mr. Grothe devolved the responsibility of carrying out the works, and he has done so with remarkable success.

ORDNANCE AND NAVAL.

Monster Ordnance.—It has been known for a fortnight past that the Government was in treaty with Sir William Armstrong for the purchase of four 100-ton guns which are near completion at Elswick, but it was considered prudent to keep the negotiation secret, as there were other bidders for the monster weapons in the European market. Arrangements are now completed by which these four guns have become the property of the British nation, and in the course of two or three months they will be ready for mounting on board any ship that is prepared to carry them. It is not likely, however, that they will be placed on shipboard for some time to come, for the Admiralty have made no provision for them, neither does it appear that the present condition of naval armaments shows any demand for such mighty ordnance. The chief argument for their acquirement was the apprehension that they might become the property of another Power, and so enable it to dominate the sea. At present, although Italy has 100-ton guns for the two latest war ships, and England has ready her 80-ton guns for her Majesty's ship Inflexible, there is no armor afloat which can resist the 35-ton and 38-ton "Woolwich Infants," which have during the last few years been produced at the Royal gun-factories in the Royal Arsenal, Woolwich, and employed in the national defences by land and sea. The subject has fully engaged the attention of the Government, and the desirability of manufacturing something heavier than the 80-ton gun has been strongly advocated, but while foreign nations plate their ships with anything less than 19½ inches of iron they are regarded as at the mercy of the 800 lbs. Palliser projectile fired by the 38 ton gun, and the authorities have consequently hesitated about taking a step still further in advance. The reflection,

however, that the Inflexible, with its 24 inches of armor-plating, would be defenceless against the 100 ton guns which Italy possesses, and some other Power might have possessed, has now induced the Government to conclude the present purchase, and, furthermore, to consider whether they should stop at this point. It is pretty well authenticated that the Italians have provided themselves with a steel-plated target which even their 100-ton gun cannot penetrate, and that they are preparing a ship which shall be defended with this armor. In view of this circumstance, the authorities were recently deliberating upon the production of a much more powerful piece of ordnance, and it was anticipated that an order would be given before long to the Royal Gun Factories for a gun of over 200 tons. The drawings for such a weapon were prepared long since, the machinery is all prepared for constructing it, and all that is required is the order to proceed. Such a gun would throw a shot of some three tons weight, and pierce three feet of solid armor. It would, however, take two years to make, and perhaps another year for experiments; but the manufacture of a ship which would have a chance even with the guns of the present day would take at least as long. It is now, however, determined that a 200-ton gun shall not be made at Woolwich.—*Engineer*.

A New Piece of Heavy Ordnance.—The Washington *Herald* says:—The Ordnance Department of the Army has constructed a large rifled gun, weighing about 90,000 lbs., with a calibre of 12.25 inches, which is now undergoing proof at the Sandy Hook proving ground, under the direction and supervision of the Ordnance Board. So far the limited firings have developed the most satisfactory results. The gun is of cast iron, lined with a coiled wrought-iron tube, with a length of bore of 227 inches, and is mounted on a carriage of late design, with all the modern improvements to control recoil and to facilitate loading and manœuvering. Although as yet the firings have been limited, still enough is known of the power of the gun to say that for use against ironclads it is equal, if not superior, to any gun of the same calibre in any service. The essential features which contribute to any superiority over others in this respect are length of bore, character of projectile and powder. In the foreign services the English 12-inch wrought iron gun has a length of bore of 198 inches; the Krupp calibre 12.008, has 222.5 inches; the Italian 12.6 has 252 inches; while the American is 227 inches long. This length adopted by the Ordnance Department gives all the usual effects that can be obtained from this source, and secures a thorough consumption of the maximum powder-charges, as has been practically proved by the absence of any unconsumed grains of powder after the discharge. The powders used have given marked superiority in velocities and pressures over those used in foreign services, the velocities being greater for corresponding pressures, and the pressures much less for the service charges. No undue pressures have shown so far from the use of the adopted system of projectiles, no erosion or guttering are apparent, and perfect rotation has resulted from the rifling and sabot employed; and this, with the absence of any stripping, has given that accuracy of flight so necessary for a successful rifled projectile. The energies attained, or rather the capacities for work—the gist of the whole subject—compare most favorably with those of foreign guns, although the difference in charges and weights of projectiles do not, so far, admit of a complete comparison; but enough is known to show that this gun has an equal, if not a greater, capacity for work of any of the foreign service rifles of like size. For instance, the English 25-ton gun has given less energy by, say, 450 foot tons, with 85 lbs. of powder and a 600 lb. projectile, than the American; and the Krupp, with 88 lbs. of powder and 664 lbs. of projectile, 1254 foot-tons less; while the Italian, with 100 lbs. of powder and 770 lbs. of projectile, has only yielded a little over 400 foot-tons more; and in these comparisons the American gun only uses 80 lbs. of powder with a 600 lb. shot. But with 110 lbs. of powder and 700 lbs. of projectile the American rifle gives 9551 foot-tons muzzle energy, or 246 foot-tons per inch of shots circumference, an energy about as great as any gun known for this charge, and decidedly superior to Krupp's and the Italian, using heavier charges. With these encouraging results, by developing a strong and durable system of gun construction, with our superior powder and projectiles, and with our rifling and length of bore, it would seem that the Ordnance Department has produced a weapon able to cope successfully with the best foreign guns, and at a much less cost.

The Electric Fuse and Heavy Cannon.—It seems as if we were about to abandon the old method of firing guns on board ship with the lanyard, and to use the electric fuse instead, at any rate, so far as heavy cannon are concerned. For some years past experiments have been carried on in the navy with electric firing, but it is only since we have had to do with very heavy guns, and particularly those in turrets, that this method of discharge has become almost indispensable. To be cooped inside a close iron turret in company with a pair of terrible weapons of 35 or 38 tons, and to experience the full measure of their thunder, is scarcely to be contemplated with indifference; yet this is not the reason, or at least not the principal reason, why the electric current is to be employed in future instead of the gunner's arm. The real cause is twofold; in the first place it is possible to take better aim by using electricity to do the work; and, secondly, the effect of the shots is more terrible. The simultaneous discharge of three or four projectiles against heavy armour has been found capable of penetrating the latter, when single shots are quite unable to do so. A vibration is set up in the iron plating, it is presumed, and in this condition the armor is more vulnerable. Simultaneous firing is impossible by hand and word of command, in the same way as gunners used to fire broadsides in the old three-decker days. To the ear the thunder of discharge might not appear otherwise in-

stantaneous, but the effect upon an ironclad is vastly different if a volley is fired by lanyards, or by a flash of electricity. The other reason is more important still. The guns are so close to the water, and the portholes so limited in size, that sighting along the weapons is frequently a matter of difficulty. The operation is much more easily performed by an officer stationed above, either in the rigging, or in the armored tower, with which most of our modern ironclads are fitted. Provided with suitable sights and electric wires which lead down into the batteries, the captain, or other officer of the ship, here has the whole of its armament under his hand. He directs at what angle the guns shall be laid, and, watching his opportunity, discharges them simultaneously at the instant he thinks most fit. Situated above the deck he is removed from the bustle and smoke below, and can act with more coolness and judgment, while obviously no time is lost when the critical moment for firing arrives.—*Standard.*

The 6-inch Armstrong Breech loader.—The experiments with a 6-inch breech-loader, submitted to the test by Sir William Armstrong, have been completed at Shoeburyness, to which place the gun was removed at the close of the preliminary experiments at the proof butts adjoining the Royal Arsenal, Woolwich, and the gun has been handed over to the maker. It has made some excellent practice, and the velocities recorded have been very high, heavy charges of pebble powder having been employed, with projectiles of from 60 lbs. to 70 lbs. in weight. The breech arrangement, which is on the French screw system, has been greatly improved by the introduction of the Elswick gas check, or "obdurator," a steel cup which expands in rear of the chamber and completes the gas-tight joint. The performance of the gun has satisfied the War Office authorities of its merits, though the simpler muzzle-loading system still has the preference, but at the same time the antipathy to breech-loading guns has so far abated that it has been decided to make a wholesale conversion of the old 32-pounder smooth bore cast-iron guns into breech-loading guns and to use them in flank defences. It has also been found more convenient to load these particular guns at the breech than at the muzzle, chiefly on account of its being necessary to mount them on carriages which do not recoil; they will fire heavy charges of case shot at short ranges.

Armor-Plate Tests.—On Tuesday, an armor-plate, manufactured by Messrs. Cammell and Co., of the Cyclops Works, Sheffield, and sub-carbonised according to the patent of that firm, was tested, by order of the Admiralty, on board the Nettle, target ship, in Portsmouth Harbor. Its dimensions were —7 feet ten inches, by 6 feet 6 inches; its thickness 9 inches, and its weight about eight tons. It was fixed to a transversal wood bulkhead, built from vertical and two horizontal layers of oak bulks, making in all 3 feet 6 inches of thickness, the whole being shored by substantial wooden spalls secured by a massive wooden thwartship. The gun used was a 12-ton 9 inch muzzle-loading rifle, and stood behind athwartship wooden bulkhead, 30 feet from the plate. The charges were 50 lbs. of battering pebble powder, and the projectiles shelled Palliser shots, 250 lbs. in weight; the muzzle velocity being 1420 feet per second, and the energy at the muzzle 3486 feet. The regulation number of rounds was fired at the plate, the experiments being conducted by Captain Herbert, of the gunnery ship Excellent, and the impact of the three projectiles formed a triangular diagram, each impact being about 2 feet apart. The first shot struck the centre of the right hand section of the plate, and penetrated 7½ inches, producing two cracks which extended from the point of impact to either side of the plate, in a slightly downward direction, and that of infinitesimal width went through the entire thickness of the plate. The second projectile was aimed at the middle of the lower part of the plate. The penetration was not only equivalent to the thickness of the plate, but the shot entered 2½ inches into the wooden backing, and considerably enlarged the two cracks, as well as loosened the left-hand corner of the plate. The final shot, however, was the most destructive in its consequences. Besides penetrating through the plate, and nearly 2 inches into the backing, it brought away almost one-fourth of the plate. The disjointure of this section commenced at the impact of the first shot, and ran in an irregular horizontal direction to the nearside, and downwards in a zig-zag fashion to the centre of the second shot, where it abruptly branched off to the lower edge of the left side of the plate. Two additional fissures were also occasioned in the upper part of the target. Mr. Wilson was present on behalf of Messrs. Cammell, and the experiments, which, judged by comparative data, was fairly satisfactory, although substantially less favorable than those with the last composite plate supplied by the firm, were watched with much interest by the captain and two chief officers of the German iron clad Konig Wilhelm.

BOOK NOTICES.

Elements of Descriptive Geometry. By J. B. Millar, B. E. London: Macmillan & Co. Price $2.00. For sale by D. Van Nostrand.

This treatise begins with the elementary geometry of the plane ; the first chapter containing about the same range of propositions as the sixth book of Davis' Legendre.

The common problems of, and straight line and plane in space are given in the second chapter.

Projections of plane and solid figures and solution of the spherical triangle form the topics of chapter third.

Curved surfaces, tangent planes and intersections of curved surfaces occupy chapters four and five, and complete the subject proper.

Axometric Projection is given in a brief appendix.

Altogether, it is an excellent work. Concisely written, beautifully printed, with excellent diagrams interspersed in the text.

METALS AND THEIR CHIEF INDUSTRIAL APPLICATIONS. By CHARLES R. ALDER WRIGHT, D. Sc London : Macmillan & Co. Price $ 1.25. For sale by D. Van Nostrand.

This treatise affords a brief outline of the metallurgy, natural history and industrial uses of most of the metals.

Chapter I : Describes metals and their sources. Chapter II : Metallurgy of the precious metals. Chapter III : Metallurgy of the more important base metals. Chapter IV : Metallurgy of the less important oxidizable metals. Chapter V : Physical properties of the metals. Chapter VI : Thermic and electric relations of the metals. Chapter VII: Chemical relation of the metals.

Thirty-three wood-cuts embellish the book.

EXPOSE DES APPLICATIONS DE L'ELECTRICITE. Par TH. DU MONCEL. Fifth volume. Paris, Lacroix. Price $ 5.60. For sale by D. Van Nostrand.

This large octavo is devoted as the title implies to *applications* of electricity.

The divisions of the subject consider in order the following topics : Railway Telegraphs ; Mechanical Applications ; Applications to the Arts ; Applications to Domestic Economy ; Production of heat ; Electric Lightning, etc., etc.

Descriptions of machines and processes are given in the fullest manner.

One hundred and seventy wood-cuts and three folding plates illustrate the work, which covers in all 672 large octavo pages.

WATER, AIR AND DISINFECTANTS. By W. NOEL HARTLEY, F.R.S.E., F.S.C. London : Society for Promoting Christian Knowledge. Price 50 cts. For sale by D. Van Nostrand.

This is one of the Manuals of Health published by the above society, and it is a work which should be in every house, as the information supplied is of everyday application and nearly affects the wellbeing of all classes of society. Much, but not too much, space is devoted to water, and recent revelations have shown that the rich as well as the poor in London are liable to disease and premature death from impure water. The propagation of zymotic disease by water receives consideration, and a chapter is devoted to its purification. Next we have an inquiry into the properties and composition of air, and some valuable hints on ventilation. It may be thought by some that it is out of the province of a religious society to publish a scientific work, but it does not need much reflection to show that it is of little use instructing people even in common morality when their surroundings are such as may be seen in London and every large town. It is true that the study of this work cannot remedy faulty coustruction, but attention to its advice will do much to mitigate it. To quote the words of Mr. Slmon, lately the Medical Officer to the Privy Council, "It is to cleanliness, ventilation and drainage, and the use of perfectly pure drinking water, that populations ought mainly to look for safety against nuisance and infection."

LE MASSIF DU MONT BLANC. PAR E. VIOLLET-LE-DUC. Paris ; J. Baudry. Price $ 12.00. For sale by D. Van Nostrand.

The structure, geological and lithological of Mont Blanc and the group of which it is the culminating point, is the subject of this interesting volume.

It would seem from the amount of detail in the illustrations, as though every acre of the area had been carefully studied.

The action of the glaciers in recent times, as well as the evidences of more extensive wear by larger ice rivers in past ages, receives a fair share of attention.

The volume contains 275 pages of text, royal octavo size, and is illustrated by 120 wood-cuts.

There are also four charts exhibiting in colors the topography of the entire region described, with profiles across all the leading summits.

THE RAILWAY BUILDEB. By WM. J. NICOLLS, Civil Engineer. New York : D. Van Nostrand. Price $ 2.00.

This is a neat pocket-book for the use of railroad men ; and is designed to afford ready aid in estimating the cost of construction of every portion of the equipment of an American railway.

Special pains have been taken by the author to render the subject clear to readers who do not find in the algebraic formula as satisfactory expression of an engineering fact.

To quite a large class of practical railway men, this plan will be considered as an acceptable, if not a superior one.

An abstract of the table of contents is herewith given :

Chapter I. Field Operations ; Corps of Engineers ; The Transit ; The Engineer's Level ; Outfit ; Running a Preliminary Line ; Transit Book ; Obstacles ; Crossing a River ; Curves ; Table of Railway Curves. II. Preliminary Surveys ; Locating the Line ; Grant of Right of Way ; Form of Contract and Proposal. III. Cost of Earthwork ; Maximum Grade ; Staking out the Work ; Average cost of Excavating ; Quantity of Earths equal to a Ton ; Tunnels. IV. Permanent Way ; Ballast ; Table of Ballasting ; Stringers ; Cross-ties ; Iron and Steel Rails ; Tons of Rails required to lay one mile of Track ; The Open Joint ; Number of Rails and Joints per mile of Single Track ; Fish Plates ; Fish Plates and Bolts required for one mile of Single Track ; Weight of Hot Pressed Nuts ; Weight of Nuts and Bolt Heads ; Bolt Heads, and Nuts ; Spikes ; Contract for Track Laying ; Trestles ; Bridges ; Weight of Iron Bridges, Wooden Bridges ; Foundations ; Culverts. V. Frogs and Switches ; Main Track and Siding ; Switches ; McCrea's Improved Chair ; Frogs ; Crossings ; Signals ; Interlocking Signals ; The Block System. VI. Equipment ; Locomotives ; Railway Cars ; Sleeping Cars ; Average weight of Car ; Coal Cars ; Wheels ; Table of Steel-tired Wheels ; Wrought Iron Frames for Trucks ; Couplings ; Springs ; Brakes ; Automatic or Continuous Brake. VII. Depots

and Structures; Passenger Stations; Freight Depot; Way Stations; Flag Stations; Turntable; Water Stations; Fuel; Properties of Fuel; Coaling Platform; Engine House; Road Crossings.

MISCELLANEOUS.

The Superintendent of the Westmoreland Coal Co., writes that a superior form of Air Duct to be used for ventilating mines, in connection with a hand fan, is in successful use in his district. It is a seamless cotton tube made by the Penn. Cotton Mill, at Pittsburgh.

We understand that Mr. E. Roberts, of the *Nautical Almanac* office, has been requested by the India office to construct for use in India a self-acting tide-calculating machine. It will be designed not only to predict the tides at open-coast stations, but also river and shallow-water tides. It will be a great improvement on the tide-calculating machine at South Kensington (now temporarily at the Paris Exhibition), inasmuch as the tides caused by the smaller lunar perturbations will be included. Each component will be fitted with a slide, so that no error will be caused from the eccentricity of the pullies. The ordinates of the curves traced by the machine being as much as eighteen inches, the use of the slides is imperative. Mr. Roberts has calculated new numbers to represent the periods of the many components, and with such success, that the actual error of any one component, after a run representing a year's predictions, will not exceed the limit of error of setting the component at the commencement. The machine will be fitted with self-regulating driving-gear, so that it can be set at the close of the day and the whole year's curves be ready for reading off by the next morning. The machine is expected to be finished towards the end of the year. Now that the immense labor (the only objection raised against the employment of tidal predictions by harmonic analysis) is superseded, it is to be hoped that the Admiralty will avail themselves of an instrument, the results of which are so vastly superior to those now obtained with considerable labor by actual computation.

A Practical test of a fire-resisting flooring was on the 6th inst. made in Victoria Street, Westminster, for the information of the Metropolitan Board of Works. The Board has the power to refuse leave to architects to erect buildings of greater height than 100ft., an objection was made to the block called the "Members' Buildings," in Victoria Street, on the score of insecurity of life in case of fire. The objection was met by the provision of fire-resisting floors, and to prove that the means taken were secure was the purpose of Thursday's experiment. A square building with 9ft. brick walls had been erected on the open space to the west of Westminster Palace Hotel, the building represented the floor of a house with windows, doors, and a corridor. A room in this building contained a quantity of materials which were set on fire, and burned for upwards of an hour. The flooring to be tested formed the roof of the building, consisting of ordinary wooden joists, cased with terra cotta tiles, and there are in the system three open spaces between the ceiling of the one room and the flooring of the room above, the room above in the experimental room being, of course, open. While the fire was raging in the room and throwing out an intense heat, the gentlemen witnessing the experiment walked above the lighted room, and proved by the application of the hand to the topmost terra-cotta tiles that the heat had not penetrated, and that the fire was limited in location. Mr. Francis Butler, the architect of the Members'-Buildings, is the inventor, and it is stated that the invention has the merit of being inexpensive, costing about 50s for 100 feet square.

Lieut. G. R. R. Savage, R.E., writing from Rookee, North-West Provinces, India, sends us an account of some interesting experiments he has been making on long-distance telephones. He constructed telephones expressly for long-distance work, and succeeded in getting a bugle-call heard distinctly over 400 miles of Government telegraph line, the wire being one of the four or five main up-country telegraph wires which are carried on one set of posts. The telephones used, Lieut. Savage constructed with about 400 ohms of No. 38 guage wire, vibrating disc about $2\frac{1}{2}$ inches diameter, the sending vibrating disc thicker a *little* than the receiving one. It seems to him right to oppose the work done at the receiving end as little as possible by having a very thin vibrating disc; while he had noticed that, *cæteris paribus*, a thicker disc approached to a telephone magnet gives a greater deflection on a distant very sensitive galvanometer, so long, of course, as it is not too thick. Lieut. Savage asks the reason for the following circumstance: Taking off the vibrating disc of a telephone, and tapping the magnet with any diamagnetic substance, brass, glass, &c., the tapping sound is heard distinctly at a distant telephone. This cannot be caused in the same way as the current in Prof. Bell's telephone; it must be caused, he supposes, by the particles of magnet being caused to vibrate longitudinally, and as the coil does not vibrate in unison with the particles of the magnet, the permanent lines of magnetic force must be cut by the coil, and hence a current. Hence, he asks, if this is the case, might not there be two causes combined producing the effect in Prof. Bell's telephone, both approach of disc and also longitudinal vibrations? Lieut. Savage constructed a small induction coil with soft iron core, the outer and inner coil the same. He heard and sent messages easily seventy or eighty miles by joining the two coils separately in circuit with the sending and receiving telephone. Of course there was no *increase* in any way, as no energy was expended on the current by the simple induction coil; there was a slight decrease in the sound. He thinks about 350 ohms of No. 38 wire makes the best coil for a telephone magnet $\frac{1}{4}$inch diameter.

PROPOSED IN
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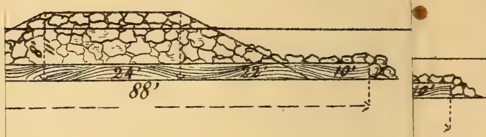
Nº 3



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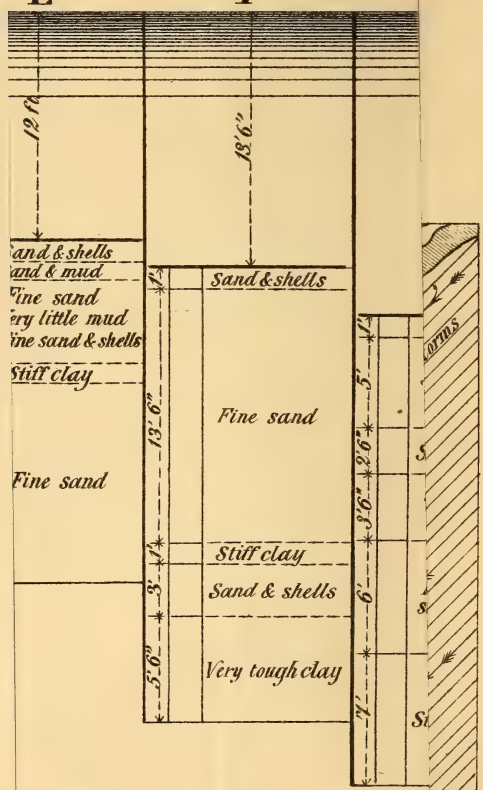


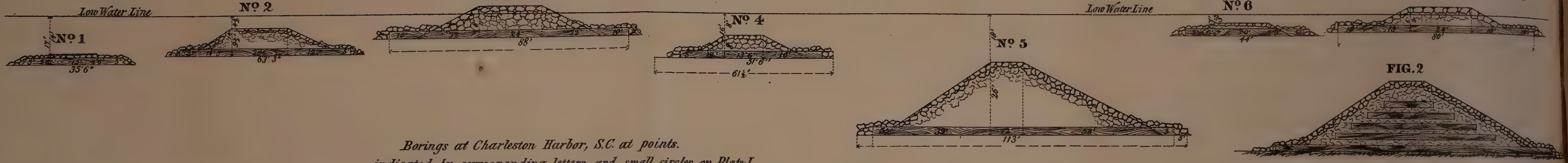
t M & N were made under authority
by Capt. J. C. Post under the orders

PROPOSED IMPROVEMENT OF CHANNEL OF ENTRANCE INTO HARBOR OF CHARLESTON S.C.

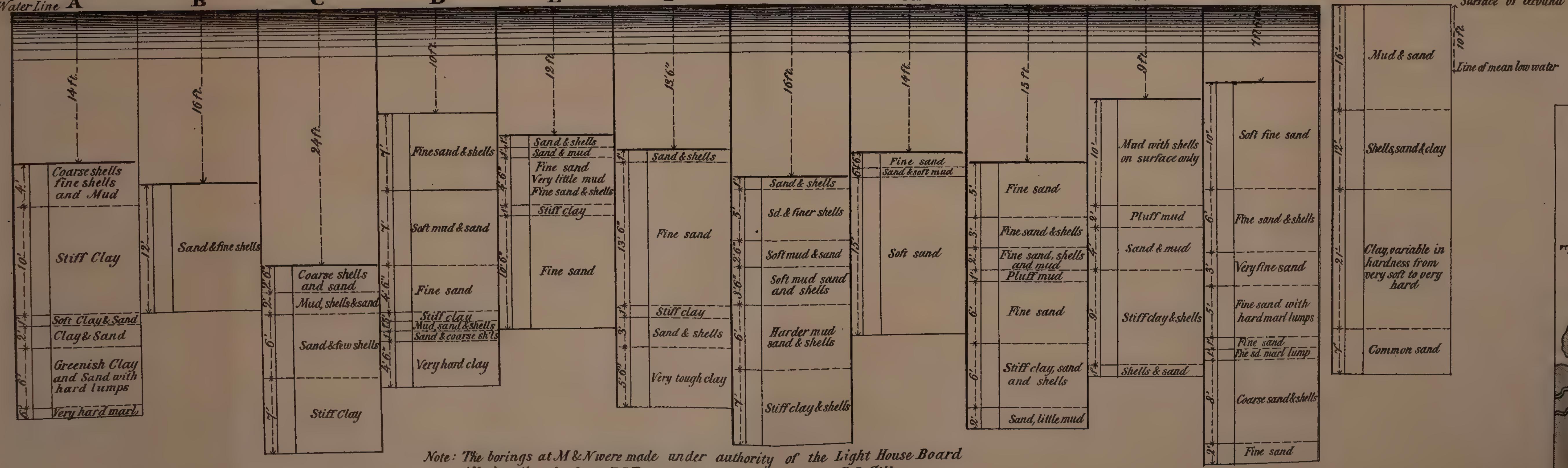
Plate III

CROSS SECTIONS

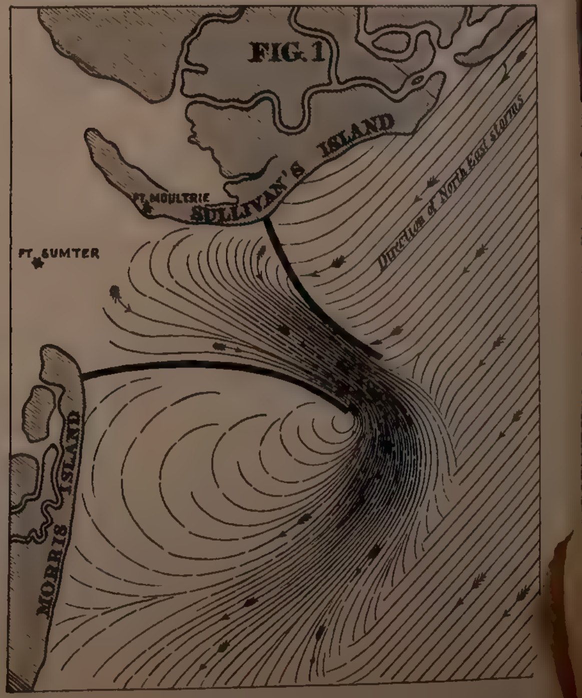
Scale for cross sections.

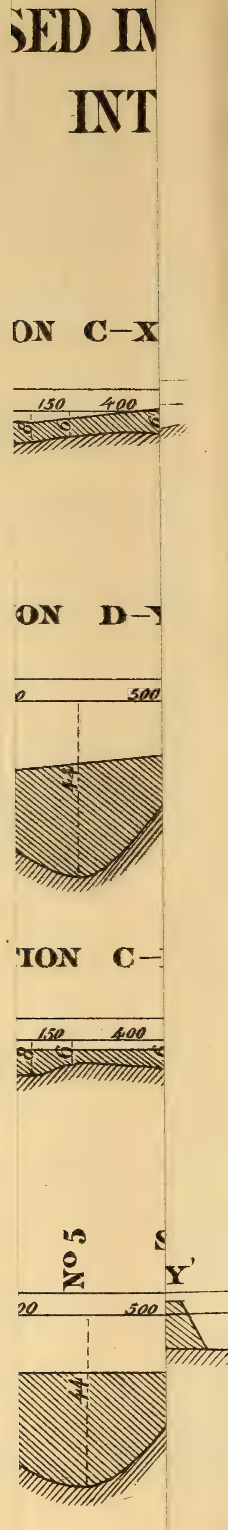


Borings at Charleston Harbor, S.C. at points. indicated by corresponding letters and small circles on Plate I.



Note: The borings at M & N were made under authority of the Light House Board All the other by Capt. J. C. Post under the orders of Lieut. Col. Gillmore.





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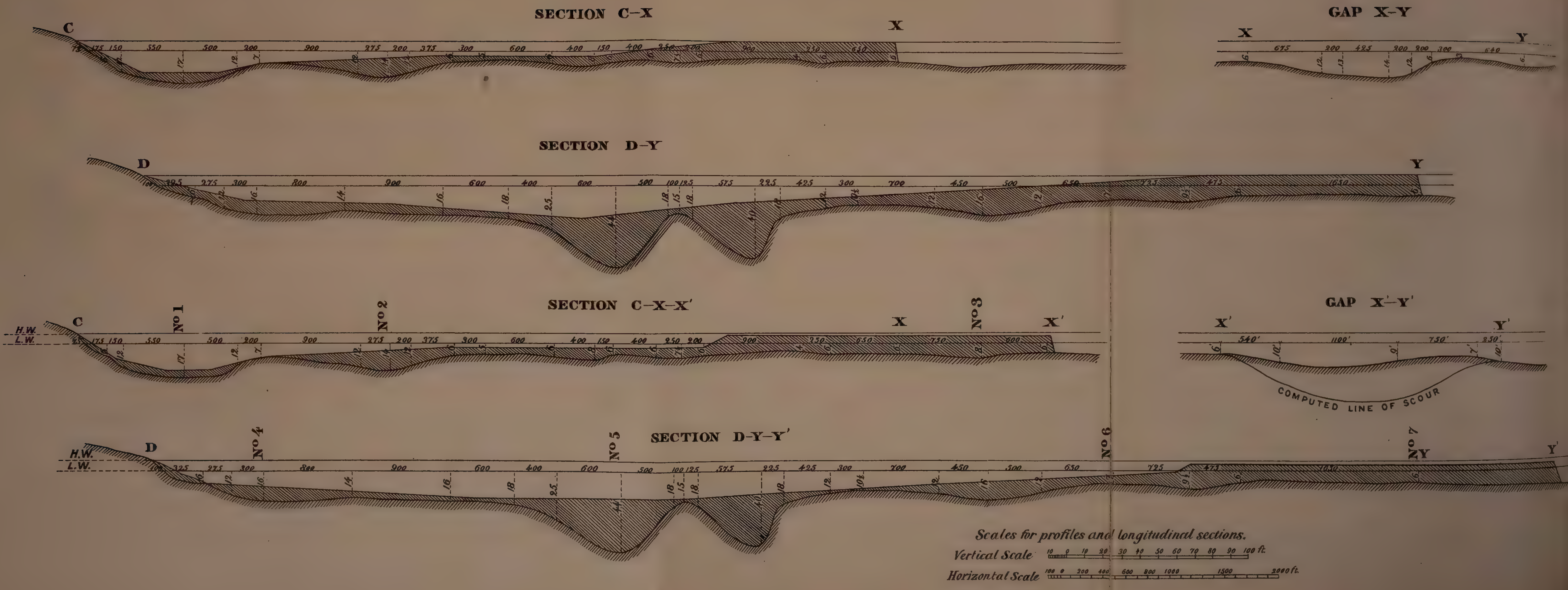
PROPOSED IMPROVEMENT OF CHANNEL OF ENTRANCE INTO HARBOR OF CHARLESTON S.C.

Plate II



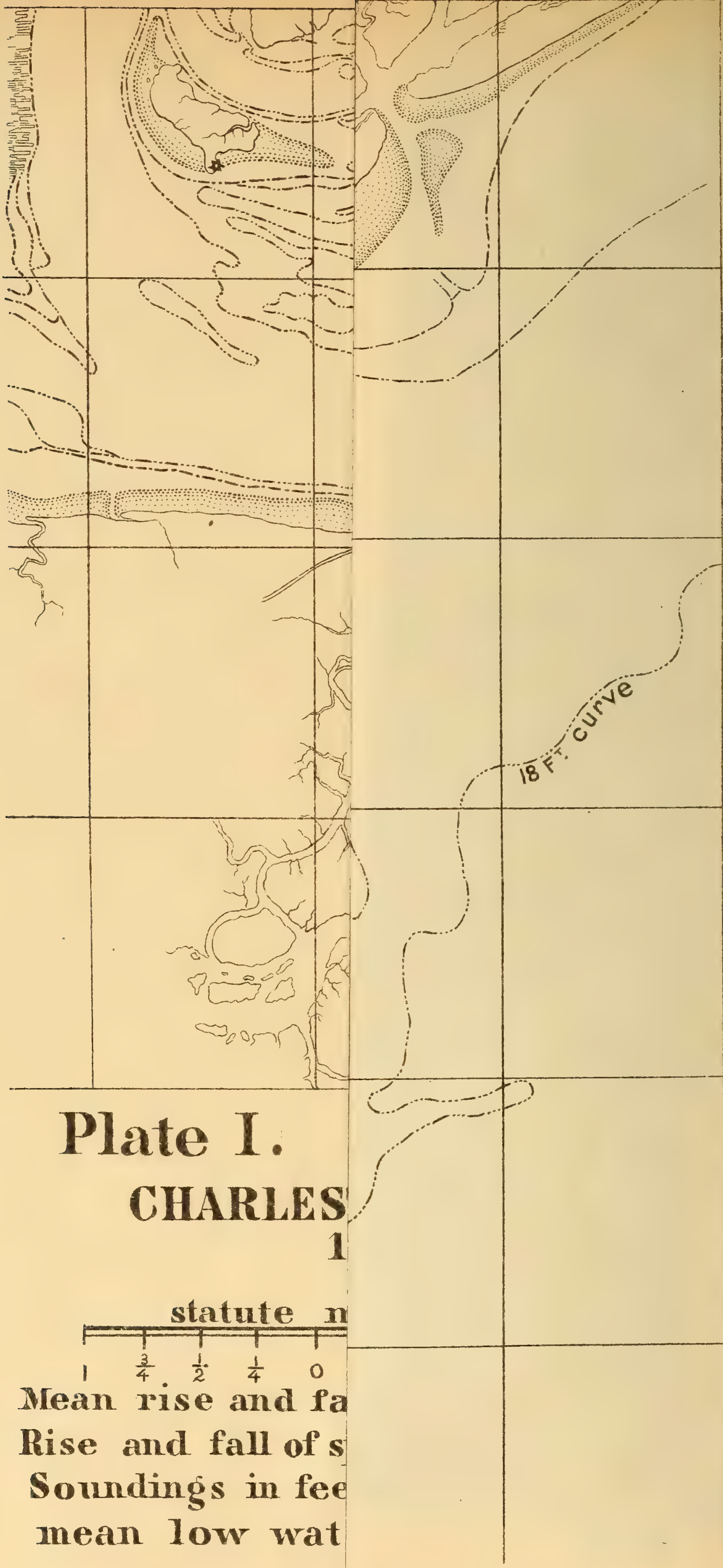


Plate I.

CHARLES

1

statute m

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A PROJECT FOR THE PERMANENT IMPROVEMENT OF THE CHANNEL OF ENTRANCE INTO THE HARBOR OF CHARLESTON, S. C., BY MEANS OF LOW JETTIES.

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THE CHARLESTON BAR.

The bar which stretches bow-shaped across the entrance into Charleston Harbor, from Sullivan's Island on the north to Folly Island on the south side, has not varied much in either location, general direction, or magnitude, within the period covered by any trustworthy knowledge which we possess on the subject.

A comparison of the chart of 1780, published in Des Barrés' Atlantic Neptune, with those of 1821, 1825, and 1851–'52, "shows that according to the earliest records the bar of Charleston has varied comparatively but little in extent, direction, or in distance, from the mouth of the harbor."

Measured along its crest, or line of least depths, the bar is ten miles in length, its north end on Sullivan's Island being close up to the entrance or throat of the harbor, while its south end, resting on Folly Island, is six miles distant therefrom. Its average width between the 18-foot curves is about $1\frac{3}{4}$ miles.

In many places the highest points of the bar are only three to four feet below the level of mean low-water, although the average depths along the crest are considerably greater.

The main central body of the bar, lying nearly due north and south, is almost straight for a length of over five miles, has its crest parallel to the main shore, south of the entrance and at a mean distance of about two miles from it, and is not at the present time, and, so far as we know, never has been traversed by practicable ship-channels.

The northern and southern extremities of the bar are formed by rather sharp curves, which connect the straight portion already mentioned with the shore above and below the harbor.

So far as we can now ascertain there appears never to have been less than four, nor more than six, ship channels across the bar at any one time. The greatest depth of water has sometimes been found in one channel and sometimes in another, being rarely less than $11\frac{1}{2}$ feet, or more than $13\frac{1}{2}$ feet, at mean low tide.

The channels, whether four or more, have always existed in two groups or clusters, one in the northern and the other in the southern curved portion of the bar, and there has always been a

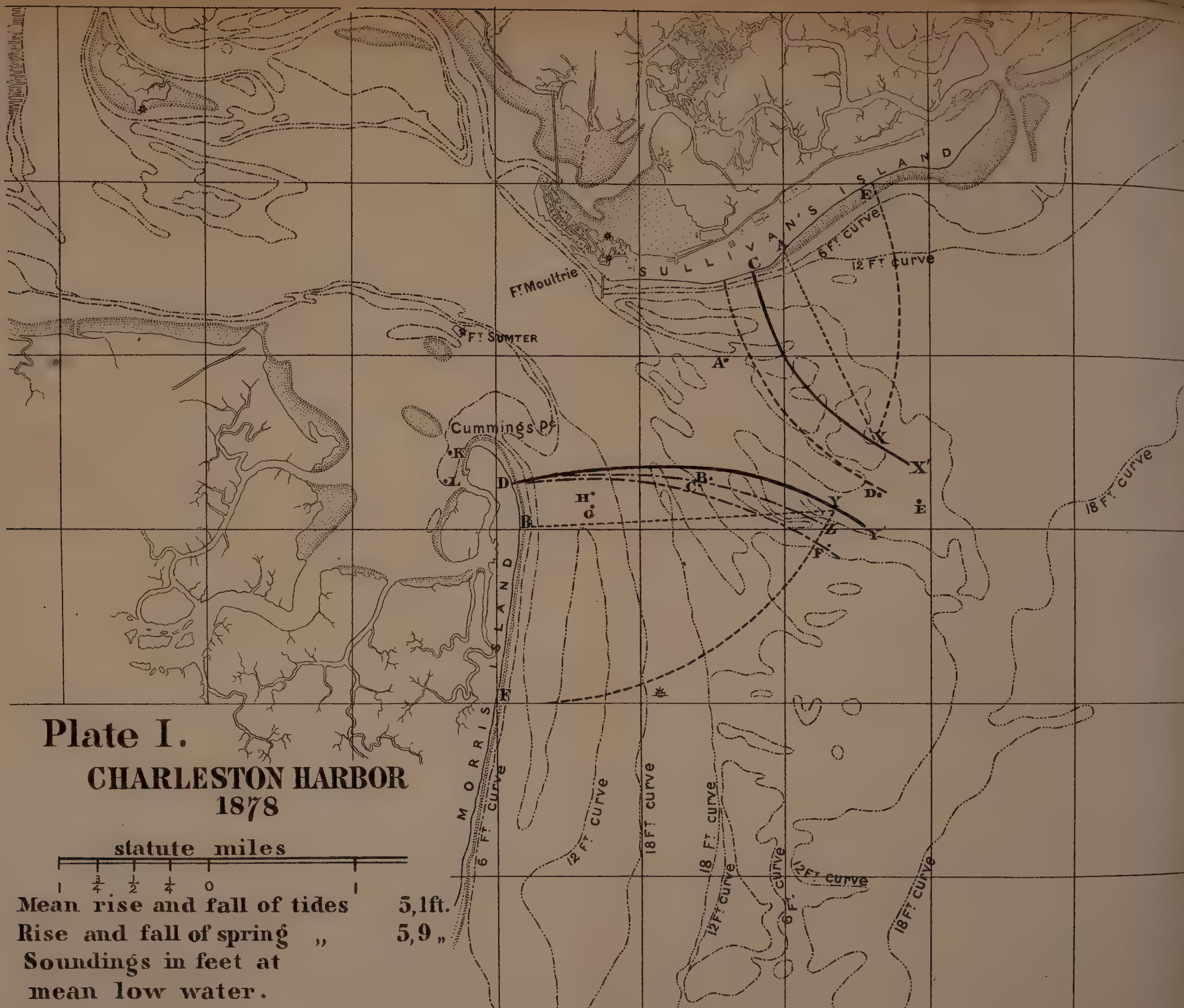

Plate I.

CHARLESTON HARBOR
1878

statute miles

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Mean rise and fall of tides 5,1ft.
Rise and fall of spring „ 5,9 „
Soundings in feet at mean low water.

deep and broad anchorage inside the straight reach of the bar abreast of Morris Island.

This anchorage, sometimes called the "main channel" and sometimes the "outer harbor" varies in width from one-third to two-thirds of a mile between the 18-foot curves, and in maximum low-water depths from 20 to 45 feet. The direction of its central line is about north and south, and its length from the throat of the harbor between Morris and Sullivan's Islands to its southern terminus, where it spreads out in various channels and shoals in crossing the bar, is fully five miles. At the extremities of this outer harbor or basin, several miles apart, are found the two groups of channels already mentioned, the most northerly group being directly in front of the gorge of the harbor.

The bar is essentially a drift-and-wave bar, produced in part by the upheaving action of the waves when they approach the shore, and are converted by breaking into waves of translation, and in part by drift-material carried along the coast by surf-currents, especially by those produced by northeast storms. The peculiar location of the bar, largely to the southward of the gorge of the harbor, and the conditions under which a very large proportion of the ebb-flow is diverted from its most direct path, and forced to skirt the main coast for several miles before it can find a passage to the sea, indicate the controlling power of these storms.

The material composing the surface of the bar closely resembles that usually found on the sea-shore between high and low water in that section of the country, being shells and fragments of shells, or silicious sand, or a mixture of them all. It is easily thrown into suspension by waves, and is moved by a moderate current.

On the north end of the bar five borings were made in order to determine the character of the substrata. The points selected for boring, and the results obtained, are indicated on the accompanying drawings.

It will be seen that below the surface there are some layers or lumps of mud, as well as of mud mixed with sand, and mud mixed with shells.

All the channels which traverse the bar are, and, so far sa we know, always have been, ebb-tide channels, produced and maintained mainly by the scour of the ebb-current, except Beach (formerly Maffitt's) Channel, the most northerly of them all, which lies close to Sullivan's Island. This is a flood-tide channel, possessing the usual characteristic of such channels, that their least depths are always found near their inner ends, and therefore in comparatively quiet water. Another distinguishing feature of such channels is that from the cross-section of shoalest soundings inward, toward the harbor, the descent into deep water is sharp and sudden, while outward, toward the ocean, it is gradual and gentle.

The North or Cumberland Channel at the entrance into Cumberland Sound, Georgia, and the Coney Island Channel of New York Harbor are of the same character. In speaking of the preponderance of the flood over the ebb in Cumberland Channel, in my report on the jetty system as applied to the entrance into Cumberland Sound, Georgia, submitted April 15, 1876, I say:

"The effect is to make the inner slope of this part of the bar very steep; the sand which is rolled along by the flood-current on the bottom of the outer slope is first brought to rest in the deep water of the inner basin. The ensuing ebb-current, which receives its velocity and direction from the large volume of Cumberland Sound, sweeps the inner slope of the northern shoals longitudinally, and takes up this sand and carries it out by the Amelia Basin, depositing it upon the main bar. The channel next to Cumberland Island is therefore a flood-tide channel, like the Sullivan's Island or Beach Channel in Charleston Harbor. They both possess in a marked degree the steep inner slope which invariably characterizes a channel maintained by the flood-tide, which having once passed in is so much diverted in its direction on the ebb, by the axial line of the tidal basin, that it cannot flow out in full volume through the same opening, but sweeps past its mouth in its passage to some more direct outlet."

Beach Channel was gauged during the months of May and June, 1876, when it was found that on a section taken 500 yards east of the inner end of the channel, at the Bowman jetty, the

volume flowing out during an entire ebb between the low water line on Sullivan's Island and the 5-foot curve on Drunken Dick Shoal, amounted to only 48.8 per cent. of the volume flowing in during an entire flood through the same section.

On a section taken 930 yards east of the Bowman jetty, between the low-water line on Sullivan's Island and the 10-foot curve on Drunken Dick, the volume of ebb amounted to 52½ per cent. of the flood.

CAPACITY OF THE TIDAL BASIN.

The area of the tidal basin formed by Charleston Harbor, as computed from the Coast Survey chart and Mills' Atlas of South Carolina, is about 15 square miles. This area is assumed to be filled during each mean flood-tide by a layer or prism of water 5.1 feet in height above the mean low-water level. In addition to this the adjacent reaches of the tributary rivers will be filled above their low-water stage by flood and back waters, which at the period of slack water-flood will form in each stream a wedge-shaped mass resting on the sloping low-water line of the river, and extending up to a point where the influence of the tidal wave ceases to produce a rise and fall of the surface of the water. The equivalent of these wedge-shaped masses, determined by simultaneous tide levels, together with the water derived from land drainage during the ebb flow, will be added to the volume of the tidal prism above mentioned.

In other words, the total volume of outflow during each ebb tide, will be measured by the volume contained between certain planes of low water and of high water, throughout the area of the tidal basin, and up the streams to points where the tide ceases to be felt, augmented by the volume derived from land drainage during the period of ebb flow.

In order to make a reasonably close estimate of the volume of outflow, it would be necessary to determine the plane of low and of high water, by a series of simultaneous water levels taken in the tidal basin and its branches, supplemented by a survey sufficiently in detail to give the high water and low water areas of the basin and branches, and an accurate topography of the marginal low lands situated between high and low water.

No investigations of this character having been made at the harbor of Charleston, the information derived from the sources above named will be mainly relied upon in this discussion.

From these data it is estimated that the average discharge through the throat of the harbor between Sullivan's and Morris Islands, on each ebb during the period of mean rise and fall of tides, amounts to a little over 3,655,443,686 cubic feet. Of this volume only about 76,571,000 cubic feet is supplied by the land drainage, on the assumption that one-half the rain-fall reaches the sea. This estimate is believed to be not too large, in view of the fact that the streams are short and in close proximity to the points of discharge.

For two or three days during the period of spring-tides, the average ebb-discharge will be augmented to about 4,228,846,000 cubic feet. The neap discharges, being in smaller volumes than those pertaining to mean tides, require no special mention, as any temporary decrease of scouring power in the new channel beyond the jetties resulting therefrom would be of short duration. Even if slight shoaling ensued during this period, the maximum depths established by mean and spring tides would be restored on the return of these tides.

The mean duration of the ebb-flow is taken at six hours, that being the average of a number of observations made by Civil Assistant George Daubeney, in 1870 and 1871, the longest flow being 6h 20m, and the shortest 5h 25m.

The average ebb-discharge per second through the gorge of the harbor during the period of mean rise and fall of tides is therefore 169,233 cubic feet ($\frac{3655443686}{21600}$), and during the period of spring-tides 195,780 cubic feet ($\frac{4228846000}{21600}$), the average rise and fall at ordinary spring-tides being 5.9 feet. No account is here taken of the somewhat longer duration of ebb-flow at average spring-tides.

During very high spring-tides the discharge will be much larger. With a rise and fall of 10.3 feet (which has actually occurred), the prism amounts to about 7,382,562,000 cubic feet, equivalent to 341,780 cubic feet per second;

nor will this show the total discharge, since the marshes will be flooded, and their area being estimated at eight square miles, every layer of water over them three inches thick will add 55,965,870 cubic feet to the prism, or 2,590 cubic feet to the average discharge per second.

It has not been deemed expedient, or likely to give trustworthy results, to attempt to gauge the flow through the gorge of the harbor by means of current-velocities. Those taken some years ago between Forts Sumter and Moultrie, with a view of locating channel torpedoes, proved the existence of eddies and counter-currents, and other irregularities of flow, to such degree, especially near the Sullivan's Island side, that the requisite accuracy seemed hardly obtainable by this method.

There is nothing specially exceptional in this, for it is known that abnormal conditions often characterize the flow of water through the gorge of a large tidal basin.

It is stated by Mr. D. Stevenson that at Cromarty Firth, where the waters pass to and from the sea through a narrow gorge, of which the width is about 4,500 feet and the depth about 150 feet:

> The mean velocity due to the column of water passing this gorge, as deduced from the observed surface-velocity, was not sufficient to account for the quantity of water actually passed during each tide, as determined by measuring the cubical capacity of the basin of the Firth. This led to the observation of the under-currents through the gorge by means of submerged floats, and it was found that during flood-tides the surface-velocity was 1.8 miles per hour, while at the depth of 50 feet the velocity was not less than 4 miles per hour, being an increase of 2.3 miles per hour. During the ebb-tide the surface-velocity was 2.7 miles per hour, and at 50 feet depth it was not less than 4.5 miles per hour, being an increase of 1.8 miles per hour.

Anomalous variations and irregularities between the surface and the sub-current have also been found to exist in the harbor of San Francisco, Cal., and elsewhere.

For the foregoing reasons, mainly, it has been thought best to use the cubical capacity of the tidal basin and the rainfall upon the drainage-area in estimating the average volume of water which flows out and in through the gorge of Charleston Harbor.

PLAN OF IMPROVEMENT RECOMMENDED.

It is proposed to construct two low jetties, one springing from Morris Island and the other from Sullivan's Island, converging toward each other in such manner that their outer ends on the crest of the bar shall be one-half to five-eighths of a mile apart. The outer ends of the two jetties will rest respectively upon the shoals lying to the northward and southward of what is known as the north channel, that being the middle channel of the north group of three channels, and having its line of deepest water located more nearly than either of the others upon the prolongation of the axis of deep-water flow through the gorge of the harbor between Cumming's Point and Fort Moultrie.

Assuming for the purposes of discussion the sea ends of the jetties to rest respectively at X and Y, it seems, in some measure, immaterial whether they be established upon straight lines as shown at AX and BY, Plate I, or upon curved lines; and if curved, whether the convexity be turned toward the central channel as at CX and DY, or from it, as at EX and FY. In either case, if kept at the proper heights, they will produce an ebb-flow through the gap able to maintain a deep channel through the bar. Neither the straight jetties, however, nor more especially those with their convexity turned away from the channel, act as training-walls to guide the outflowing water. The curved jetties convex toward each other, being less open to this objection, are the ones adopted in this project.

The north jetty starts from a point on Sullivan's Island 1,800 yards east of Bowman's jetty. The half next the shore is curved to a radius of about 1½ miles, the outer half being very nearly a straight line. The total length of this jetty from C to X is 7,450 feet, and its general direction is southeast.

The south jetty, having a total length of 11,650 feet from D to Y, starts from Morris Island at a point about 650 yards from Cumming's Point, its general direction being east. The shore end is curved to a radius of about three miles for a little more than one-half its entire length, while the half next the sea is nearly straight, as in the case of the north jetty.

The specified length of the jetties is

taken for purposes of discussion. As will be seen hereafter, they would not be able to produce a channel of the requisite capacity through certain materials which are likely to be encountered in the bar, although they would be expected to maintain such a channel if once established.

The outer ends of the two jetties slightly converge toward each other as they approach the crest of the bar, and are intended to act as training-walls for a distance, in each case, quite equal to half its entire length. These portions lie in the direction of the flood-currents, and may be built to any height without obstructing the inflow. For fully one-fourth of their entire length the sea ends could be carried above the level of high-water, so as to be visible at all stages of the tide.

The characteristic feature of the design—that of low jetties—is intended to maintain the bar in its present general location, with such moderate increase of magnitude as may be expected to result from concentrating upon a gap one-half to five-eighths of a mile in width, a portion of the water which is now dispersed over a width of ten miles.

The complete success of the works is believed to depend on three important conditions, which they are expected in great measure to satisfy, and which have been kept in view in preparing the design, viz:

1. *They should not impede the inflow to such degree as to prevent the tidal basin being filled as now at every influx of the tidal wave.*

To this end the inner half of each jetty, more especially its central portion, located in deep water across the thread of the current, is kept several feet below the water. The outer half, being nearly parallel to the direction of the flow, is built higher, and the sea end, for a distance of several hundred feet, may be carried up to high water level, or higher.

2. *They should control the outflow to such degree and in such manner that a channel of the required depth will be maintained through the bar.*

To this end, although a large portion of the *surface flow* will spread out over the tops of the jetties and thence over the bar, the *central flow*, throughout the entire depth along the axial line of the gorge between Sullivan's and Morris Islands, is aided in its natural tendency to reach the sea along the prolongation of that line, by the opening left for it between the jetties. The *bottom-flow* through the gorge of the harbor is deflected on converging lines by the jetties, and is therefore forced in a measure to concentrate itself in, and flow out through the gap between them. The outer half of each jetty and the adjacent portion of the shore end act as a training-wall for this flow.

3. *They should not to any considerable extent cause a movement seaward of the main body of the bar; that is, the general position of the bar should be independent of the effects produced between and beyond the heads of the jetties.*

It is believed that this condition will be secured by making the shore ends of the jetties low for at least one-half their length, or throughout those portions which cross the thread of the current in deep water, so as to allow the tide to ebb and flow somewhat freely over them. The effect of high jetties, with a correspondingly wide gap between them to allow a full influx of the tide, would tend to transfer the gorge of the harbor from its present position to the sea ends of the jetties, two and a half miles distant, and move the shore line out to that point, by causing a filling in of the exterior angles between the jetties and the shore. After reaching this stage, a drift-and-wave bar would probably be found to the seaward of the present bar, in front of the jetties, rendering it necessary to extend them in order to cut a passage through it.

It seems essential, therefore, that the agencies which maintain the present bar should remain in as full force as possible, consistent with the requisite concentration of outflow between the jetties.

The probable effects will be that the bar will be raised somewhat throughout its entire length, the waves will break upon it more frequently than now, and considerable shoaling will, of course, take place in Beach Channel and in all the southern group of channels. But it is believed that the important condition of keeping the bar generally in its present position will be secured.

The drift-material carried along the coast by surf-currents, as well as the sand thrown up by the breakers on the

north and south shoals, instead of lodging in and filling up the exterior angles between the jetties and the shore, as in the case of high jetties, will be disposed of in a harmless manner.

For example, a heavy northeasterly storm, producing breakers along the north shoal, and strong southerly surf-currents along the shores of Long and Sullivan's islands, would put in motion a large quantity of material, a portion of which would be carried in by the flood-currents over the north jetty and through Beach Channel, coming to rest in the deep water of the main channel. It would next be taken up by the ebb current and rolled out to sea between the jetties. Beyond the jetty-heads it would encounter the littoral ebb-current, moving to the southward with a velocity accelerated by the storm, by which it would be again carried in a south-westerly direction until finally, left to the action of the south breakers, it would be either deposited temporarily upon the south shoal, or carried still farther to the southward. This action, which would be incessant during the continuance of the storm, is illustrated in Figure 1, Plate III.

The action of a southerly storm would be the reverse of this. In either case some drift-material would be carried by waves and surf-currents around the jetty-heads, and would subside in the deep water between them, to be swept out by ensuing ebb-currents, and disposed of to the northward or southward, according to the direction of the storm.

This movement of sand was referred to in my report on the improvement of the Fernandina Bar, submitted April 15, 1876, from which the following extract is made:

As a moderate assumption, a northeaster of three days' duration might be expected to lower the north shoal four inches within the area covered by the breakers. The greater part of the eroded material, amounting to upward of 516,000 cubic yards, would doubtless be distributed along the south shoal during the progress of the storm. If the waves should subside, or a southerly or southeasterly storm set in before the bar channel had returned to its nominal condition, the material subsequently carried out would not reach the south shoal, but in the former case would remain near the outlet on the outer slope of the bar, and in the latter would be carried back by the waves to the north shoal. If as much as one-fourth of it remained in the bar channel between the inner and outer eighteen foot curves, a few severe storms such as frequently occur within the period of a single month would entirely destroy it, by filling it up to the level of the shoal on either side.

It would appear, therefore, that millions of cubic yards of the material composing the bar might be shifted back and forth from one side of the channel outlet to the other during a single season, without causing injury to the channel by shoaling, and without producing any changes in the form and location of the bar itself, that might not entirely escape the notice of the most careful surveyor. And yet this shifting of material of which no evidence may be left behind, should enter as an important, if not a controlling function in the project of the engineer, because the useful life of his works is more or less dependent thereon.

As no works can be expected to stop this movement of drift-material for any great length of time, they should, if practicable, accommodate themselves to it under conditions of a permanent character. Those proposed are designed to do this, by allowing the drift-sand to move from one part of the bar to the other in much the same manner as now, never remaining in the jetty channel longer than a few tides, and never finding a resting-place anywhere that the next storm may not disturb.

PROBABLE EFFECT PRODUCED BY THE JETTIES.

An attempt is made below to determine by the use of appropriate formulæ the principal phenomena of the ebb-flow, after the jetties shall have been constructed and an enlarged water-way of the greatest self-maintaining area has been established between them, and the hydraulic equilibrium has been restored.

The jetties in this discussion are first assumed to occupy the lines CX and DY, Plate I, with their respective crests established at the varying heights shown by the longitudinal sections CX and DY on Plate II, the sea ends being half a mile apart. The north jetty crosses the deep water of Beach Channel at the level of twelve feet below mean low-water, the crest being held at that level for a length of about 650 feet, whence it rises gradually by gentle slopes to high-water at each end. On the sea end the part carried to high-water level is 1,500 feet long.

The south jetty, designed on a similar plan, crosses the main channel on a level

fifteen feet below mean low-water, the seaward end for a length of 2,000 feet having its crest at high-water.

The sectional area of the gorge profile between Morris Island and Sullivan's Island is as follows:

	Square feet.
Area of low-water section....	159,550
Area of high-water section...	195,350
Mean ebb-tide area..........	176,600

The width of the surface at half tide, corresponding to the mean ebb-tide area is 6,825 feet, and the wetted perimeter 6,927 feet. The hydraulic radius is, therefore, 25.46 feet.

At mean low-water the surface width is 6,750 feet, the wetted perimeter 6,851 feet, and the hydraulic radius 22.29 feet.

The area inclosed between the line of gorge at Cumming's Point (Morris Island) and that of the proposed jetties and gap is 2.16 square miles.

The average discharge per second across the proposed sites of the jetties and the gap between them is, therefore, 183,451 cubic feet

$$\left(\frac{3,655,443,886+307,108,434}{21,600}\right)$$

or 14,218 cubic feet more than the amount flowing out at the gorge.

The following are the sectional areas in square feet now existing on the lines proposed for the jetties and gap:

	Low water.	Mean half tide.
	Square feet.	*Square feet.*
Line of north jetty.	59,900	78,880
Line of south jetty.	171,720	201,365
Gap..............	22,840	29,572
Totals.........	254,460	309,817

For the following calculations the D'Aubuisson-Downing formula will be used, not because it is the best, but mainly because it is very simple and easy of application. It is, moreover, believed to answer very well in cases of broad open streams.

The formula is

$V=100\times\sqrt{s}\times\sqrt{r}$, in which

V=velocity in feet per second.

s=slope, or ratio of horizontal length to vertical descent.

r=hydraulic radius in feet.

In the gorge at Cumming's Point the grand mean of all the velocities is .958 feet per second $\left(\frac{169,233}{176,600}\right)$.

The grand mean of all the velocities with which the water passes through the various compartments of the present section along the line of the jetties and gap is 0.59212 feet per second $\left(\frac{183,451}{309,817}\right)$.

The mean hydraulic radius of this aggregate section is 14.0322 feet

$$\left(\frac{309,817}{7,574.3+2,679.7+11,825}\right).$$

Therefore

$$V=0.59212=100\sqrt{14.0322}\times\sqrt{s}.$$

$$\sqrt{s}=\frac{0.59212}{100\times\sqrt{14.0322}}=0.0015807$$

$$s=0.000002498.$$

On the assumption that this slope is the same throughout the section (which in point of fact is not precisely the case, and we have no data for making the necessary correction for the several compartments), the total average volume of discharge per second, amounting to 183,451 cubic feet, is distributed as follows, as determined by the various areas and hydraulic radii:

	Cubic feet.
Through present section on site of north jetty....................	39,418
Through present section on gap......	15,227
Through present section on site of south jetty.....................	128,806
Total as above..........	183,451

This will be assumed to represent the present distribution of the outflow per second through the section selected for the sites of the works and the opening between them at its narrowest point.

The changes of regimen which the jetties will tend to produce, and the area of the water-way which once established they would be expected to maintain between and beyond the sea ends, will next be considered.

The north jetty will reduce the half-tide area of the water-way from its present area of 78,880 square feet to 41,593 square feet, and the hydraulic radius from 10.41 feet to 7.59 feet.

The south jetty half-tide water-way

will be reduced from the present area of 201,365 square feet to an area of 94,684 square feet, and its hydraulic radius from 17.03 feet to 10.77 feet.

These hydraulic radii are to be considered permanent, the crests of the jetties being supposed to be able to resist abrasion by the current.

In the gap, where alone erosion can take place, the present mean half-tide water-way is 29,572 square feet, and the mean low-tide area 22,840 square feet.

After the jetties shall have achieved their maximum scour, aided by dredging or other artificial appliances wherever clay-beds are encountered, and the equilibrium of flow is resumed, the original general average slope S=0.000002498 will be restored.

The aggregate average discharge per second before the jetties were built will also be restored.

From these premises the following average discharges per second are found:

	Cubic feet.
Across crest of north jetty............	18,113
Across crest of south jetty............	49,110
Total over the jetties..........	67,223

The balance of the discharge, amounting to 116,228 cubic feet per second (183,451—67,223), will go out through the gap between the jetties, where at present there is a mean half-tide area of only 29,572 square feet and a mean discharge of 15,227 cubic feet per second.

The formula already used gives for the average velocity through the gap:

$$V=100\times\sqrt{s}\times\sqrt{r}$$

Substituting the value $\sqrt{s}=0.0015807$, we have

$$V=0.15807\times\sqrt{r}$$

The value of r is unknown. The width of the gap being 2,640 feet, we have for the wetted perimeter, by General Abbot's rule, 2,680 feet (2,640×1.015).

If A represent the unknown half-tide area of the gap in square feet, we have

$$r=\frac{A}{2,680}$$

and

$$v=0.15807\times\frac{\sqrt{A}}{\sqrt{2,680}}$$

The calculated average discharge through the gap per second being 116,228 cubic feet, we have

$$116,228=Av=A\times\sqrt{A}\times\frac{0.15807}{\sqrt{2,680}}$$

$$A=\sqrt[3]{\left(\frac{116,228\times\sqrt{2,680}}{0.15807}\right)^2}$$

$$A=113,160 \text{ square feet.}$$

The mean hydraulic radius at the gap will therefore be 42.22 feet $\left(\frac{113,160}{2,680}\right)$ at mean half tide, or 39.71 at mean low-water. This implies very considerable mid-channel depths.

In the profile between Fort Sumter and Sullivan's Island, having a mean low-water area of 177,620 square feet, a width of 4,960 feet, and a hydraulic radius of 35.28 feet, fully ninety per cent. of the total area pertains to depths of twenty-four feet and upward, occupying a width of 3,540 feet, in which the maximum depth is seventy-six feet.

On the profile from Cumming's Point to the Bowman jetty, the low-water area is 159,550 square feet, the width 6,750 feet, and the hydraulic radius 23.29 feet. The compartments of twenty-four feet depth or more form eighty per cent. of the whole section, and occupy a width of 3,000 feet, with maximum depths close up to seventy feet.

In the new channel between the jetty-heads, where the hydraulic radius is 39.71 feet, it may be expected that the area of depths of more than twenty-four feet will constitute a very large proportion of the total area of the gap, and that maximum depths of seventy-five feet and upward would be maintained in mid-channel.

The average velocity from which the general average slope is derived is, of course, less than the velocity that will prevail in the deep channel compartments of the profile, since with unaltered slope the velocities in different portions of the profile may be considered to vary as the square root of depths. The grand average velocity in the profile between Cumming's Point and Bowman's jetty, with a mean hydraulic radius at half tide of 25.46 feet, is .958 feet, per second; in the 50-feet compartments the *average* velocity would be 1.33 feet per second; while during the second and third quarters of ebb the velocities will vary between two and three feet per second.

The bottom velocities will generally be but little less, to judge from the results of a great number of current observations made near Fort Sumter by Capt. William Ludlow a few years ago.

Of the effects that will be produced to the seaward of the jetties upon the outward slope of the bar, by so large a volume of outflow, it is impossible to deduce from formulæ, results upon which reliance can be safely placed. We know what kind of effects will ensue, but we have no precise measure of their intensity. The first and greatest difficulty met with is the want of trustworthy data concerning the rate at which the water, as it issues forth from the gap, will spread out and disperse over the descending outer slope of the bar, with a diminishing velocity and scouring power. For the purpose of discussion, it will be assumed that the currents having passed the jetty-heads will spread out in a fan-shaped area, at an angle of thirty degrees on each side, with the axis of the new channel. The chart seems to indicate that this angle is not too small. It is, however, largely conjectural.

Assuming, however, a total spread of sixty degrees, the width of the profile $1\frac{1}{2}$ miles to seaward, through which the outflow from the jetties is supposed to pass, is 10,933 feet.

By adding the fan-shaped water-prism between the jetty-heads and the seaward profile to the volume of flow through the former, we find that the average volume passing through the outer profile will be 128,916 cubic feet per second.

The half-tide sectional area of the profile is found, by the method of calculation already employed, to be 172,312 square feet. Its wetted perimeter is 11,097 feet, its hydraulic radius at mean half-tide 15.52 feet, and at mean low-water about 13 feet, which implies more than ample mid-channel depths through the outer slope of the bar for vessels of the deepest draught.

As this outer profile is taken upon the seaward slope of the bar a little beyond the eighteen foot low-water curve, the permanent depths first secured there—permanent because representing a restored equilibrium—can, of course, be increased at pleasure, and at a small relative cost, by the moderate extension of the jetties.

If the gap between the jetties be widened, the submerged portions must be raised to a greater average height, thus diminishing the area of water-way above them, in order that a channel of the same mean depths in the seaward profile near the outer eighteen foot curve, above deduced for a specified height, may be maintained. Considerations of cost furnish strong arguments for keeping the crest of the jetties low, as the expense of added height in jetties with side slopes increases much more rapidly than the height itself. For example, a wall ten feet high and ten feet wide on top, with slopes of forty-five degrees, contains 200 square feet in cross section, while a wall of the same width on top and only twice the height contains three times that area of cross-section. By doubling the height the quantity of materials required is therefore trebled in this case, and more must be still added to compensate for the increased subsidence caused by doubling the weight on the foundation. By trebling the height we get six times the area of cross-section.

With an opening between the jetties five eighths of a mile wide, established by swinging the south jetty to the southward around its shore-end as a center until it occupies the line DZ, and leaving the north jetty located on the line CX, as before, it will be necessary to raise the submerged portions an average of about 14 inches higher than the crests shown on the longitudinal sections CX and DY, Plate II, in order to maintain in the seaward profile $1\frac{1}{2}$ miles from the jetty-heads, the same hydraulic radius deduced for the half-mile gap. Between the jetty-heads the hydraulic radius for the five-eighths mile gap would be about 4.45 feet less than for the half-mile gap. Under both suppositions the sea-ends of the jetties rise to high-water level for a length of 1,500 feet on the north jetty, and 2,000 feet on the south jetty.

There seems to be little room for doubt that a channel of ample capacity having been once established through the bar, it will be permanently maintained by the jetties, and that the materials more or less constantly carried out by the current,

especially during the prevalence of drift-producing storms, and immediately subsequent thereto, will not be deposited under conditions favorable to the formation of an exterior bar.

The outer slope of the bar, directly to the seaward of the jetties, will perhaps assume and maintain a salient form in consequence of the materials being first brought to a temporary rest at that point ; but unless the main body of the bar to the northward and southward of the jetties also moves bodily to the seaward in a marked degree, in violation of all known or suspected laws, the movement of drift will go on substantially as at present, finding only a transient resting place in front of the new channel, or upon any other portion of the bar.

Having assumed the width between the jetties and the points on the bar at which their sea-ends should rest, it is not claimed that the corresponding height capable of maintaining through the bar, to deep water on the outside, a channel of a specified capacity, can be determined with precision by computations based on the use of any known formulæ. But it seems quite clear, with the large surplus of available water not needed between the jetties, that we can by first building them low throughout their entire length, and then raising them gradually to the required height, utilize the flow, and accomplish the desired results, not only with certainty, but with the greatest attainable degree of economy.

It will be expedient, from other considerations, to proceed gradually in raising the works to the requisite height. It will be seen from Plate III, containing a record of the borings, that at the point D, nearly in the axis of the new channel, and a little outside a right line joining the sea-ends of the jetties, a bed of "soft mud and sand," 7 feet in thickness, is encountered at a depth of 5 feet below the bottom, and 17 feet below mean low water. It overlies a bed of sand 4½ feet thick. At E about 460 yards to seaward of the point D, and also in the line of the new channel, a layer or thin bed of sand, shells, and soft mud, only 1 foot thick, is found 1 foot below the bottom, and 13 feet below low water. At a depth of 6½ feet, a 1-foot bed, or lumps of stiff clay exist, resting on 10½ feet of fine sand. At A, more than 1¼ miles inside the jetty head, and a little to the northward of the probable line of deepest water, a bed of tenacious clay is found 4 feet below the bottom, and 18 feet below low-water, while outside the gap at F, about half a mile in a southerly direction from D, no clay or mud is found until a depth of 28 feet below low water is reached, and there it is only a foot thick, and rests upon 3 feet of "shells and sand."

These borings show that the material which may be found capable of resisting erosion and removal by the currents does not occur in continuous and regular strata, but apparently in detached sheets, lumps, and beds, varying greatly in thickness and in depth below the bottom, and below the water-level.

It is presumed that none of the materials which it would be necessary to remove, in establishing a deep water-channel through the bar, can be eroded and carried off by the currents, except those designated in the table of borings as "shells," "sand," "soft mud," or a mixture of two or all of them. Whenever stiff clay is to be removed some method of dredging or harrowing will have to be adopted, and it may be necessary to resort to harrowing in aid of the natural scour, to get rid of some of the beds of mud and softer clays. The sand and shells will be carried out by the current.

When the jetties, supposed for the present to be built of riprap resting on a mattress of fascines, have reached their full length, or rather their assumed length, from the shores to the points X and Y, respectively, with heights throughout the submerged portions not much greater than may be deemed necessary to secure the foundations from injury by undermining, the lower sections should then be gradually built up until a sufficient flow is established between them to scour off the surface-layer of sand, shells, and soft mud, and lay bare the beds of stiff mud and clay between the heads of the jetties, and as far beyond them as possible, consistent with the safety of the works themselves. The greatest effect will naturally be produced along the center line, and the volume of flow should not be made large enough to cause any considerable scour along the faces of the jetties.

Dredging, if it becomes necessary at

all, should begin along the line of greatest scour as soon as the removal of the clay by that method becomes practicable, and as greater depths are secured in this manner the jetties should be raised to higher levels.

The borings indicate that sooner or later, during this stage of progress, it will become necessary to determine in what manner the needed depths to seaward upon the outer slope of the bar can best be established. It may be done either by enlarging the area of the water-way between and directly in front of the jetties, so as to lengthen the outward reach of the scouring power, or by extending the jetties themselves further out on the bar, with only moderate depths between them, thus carrying further to seaward the point at which divergence and consequent loss of power begin. In the degree to which the first method, if adopted, is carried into execution, will the jetties approach the heights shown in sections CX and DY, Plate II, and they could not theoretically attain and exceed those heights until the channel in the gap has a mean half-tide area of 113,160 square feet, and a hydraulic radius of 42.22 feet. This implies, as already stated, a deep central channel with maximum depths, which would perhaps be impossible of attainment at moderate cost by any known process of dredging or raking.

The boring at D, in the line of the new channel, indicates that very little dredging or raking would have to be done to reach a depth of 31 feet below mean low-water, there being only 6 inches of stiff clay to penetrate in that distance, and that is found at a depth of 28½ feet. At E, farther out on the same channel line, only 12 inches of stiff clay is encountered in a depth of 30 feet. Whether this material occurs nearer the surface, or in thicker beds, at other points where its removal would be necessary to give the requisite water-way, cannot, of course, be known from the examinations that have been made. Very numerous borings taken near each other would be necessary before even a very general estimate could be made of the quantity of materials of different kinds that would require removal by other agencies than the natural scour, in order to attain any given area of water-way.

It is probable that the thin deposits of clay encountered in boring are only detached lumps or small masses that will be no obstacle to the prosecution of the work, but will settle down to lower levels as the sand is scoured away from around and beneath them. The existence of such lumps on the bottom of the inner harbor has been reported by divers.

For the purpose of this estimate, maximum mid-channel depths in the gap of only 31 feet at mean low-water will be adopted, because that depth appears to involve only a small outlay for dredging, and possibly none at all.

By fixing the crests of the submerged portions of the jetties at the requisite heights, we have the means of maintaining in this water-way average depths not much less than the maximum depths, thus producing a wide channel with moderate depths, instead of a narrow channel very deep along the central line and shoal toward the sides. Under these conditions the hydraulic radius in the gap can be made comparatively large. It will be taken at 24 feet mean half-tide.

It appears from calculations based, as before, on an assumed divergence of 60 degrees in the ebb flow exterior to the jetty-heads, that a normal flow through the half-mile gap, with a hydraulic radius of 24 feet, cannot maintain a channel exceeding 21 feet in depth at mean low-water, for a greater distance than about 5,500 feet beyond the heads of the jetties where the divergence begins. This would require the jetties to be 2,400 feet longer than jetties CX and DY, already discussed, although their submerged crests would be somewhat lower. The north jetty, if kept generally parallel to the bottom, would not exceed 1 foot in average height, its office being mainly to prevent the enlargement of the Beach Channel water-way by scour. The south jetty would have its submerged crest at 10.78 feet below mean low-water, if kept level throughout. Under these circumstances, with a 24-foot hydraulic radius in the gap, and corresponding hydraulic radii in the seaward profiles, on the supposed total divergenee of 60 degrees, the original slope will be restored. The mean average ebb velocity through the gap will be 0.93 foot per second.

By raising their submerged portions above the calculated heights, last mentioned, greater ebb flow and velocities would be established in the gap, with correspondingly increased power and outward reach, and, therefore, increased depths through the outer slope of the bar into the deep water beyond. But this would give no greater depths in the gap, under the supposition that beds of clay exist there at and below the depth of 31 feet, the only condition which appears to impose the necessity of low jetties at all.

If the submerged crests be placed at the varying heights shown in sections CX′ and DY′, Plate II, the total areas over the jetties and through the gap will be somewhat diminished, and as the areas are all fixed, while the volume to be discharged remains the same, there will ensue in the gap a banking up of the waters and consequently an increase of slope and of velocity. The computations show that the natural slope of 0.000002498 or about $\frac{5}{32}$ inch to the mile, will be increased to 0.000004963, equal to about $\frac{5}{16}$ inch per mile; and the previous mean average velocity of 0.93 foot per second will be augmented to 1.09 feet per second. At what distance beyond the jetty-heads the original slope will be resumed cannot be ascertained by any process of computation, and consequently the distances beyond the points X and Y, to which the jetties should be carried in order to maintain a channel of the required depth through the outer slope of the bar, is largely conjectural. It is certain that they will not have to be extended as far as in the case of the low jetties last discussed. The calculations show, however, that, with the assumed divergence of 60 degrees, the heads of the jetties, or the point where divergence begins, need not be located more than 1,390 feet to seaward of the points X and Y, Plate I. This, theoretically, places their heads at X′ and Y′, respectively.

The practical solution of this question would of course be given by a gradual and cautious building up of the jetties, with frequent observations of their effects, care being taken that they are not raised so high as to prevent the complete filling of the tidal basin by each flood.

Additional borings would of course be made before definitely fixing the width between the jetties, as it is possible that beds of material incapable of removal by natural scour may exist at such moderate depths that the half-mile gap should give place to a considerably wider one, a question which will doubtless turn mainly on the quantity of materials that may require to be excavated by dredging.

No change of this character and for this purpose, if judiciously made, would materially alter the estimated quantities of materials needed for the construction of the works.

The volume of water, a little more than thirty-six hundred and fifty-five millions of cubic feet (3,655,374,296), which is supposed, in the foregoing discussion, to pass out through the gorge of the harbor on each ordinary ebb-tide, is believed to be less than the actual outflow of one tide.

Computations, in all respects similar to those given above, have been made on the supposition that the volume of outflow during each or ordinary tide, is 4,834,000,000 of cubic feet, which is believed to be somewhat in excess of the actual outflow.

The computed hydraulic radius in the gap between the jetties, is the same in both cases, which was to be expected, for the reason that we have only the calculated slopes and mean velocities to deal with, and that these vary with the volume of flow through the same section. The actual slope and velocity may be assumed to lie somewhere between those deduced in the two cases, and therefore, to correspond to the deduced hydraulic radius. These theoretical results are of practical value only when they point to bottom velocities possessing a scouring power of sufficient intensity to maintain the new channel. In the case under discussion, they theoretically satisfy that condition. Greater velocities could, of course, be established between the jetties by raising them higher, and in the seaward profile by extending them further out upon the bar.

It is quite likely that there would be an advantage in locating the sea-ends of the jetties about one-fourth of a mile to the southward of the points indicated on Plate I. This would place the center of the half-mile gap at the point Y;

where the sea end of the south jetty is placed in the drawing, and would turn the axis of the new channel more away from the prevailing storms which come from the northeast. The jetties in these positions are shown in Plate I, by heavy broken lines. It is not intended in this project to fix definitely either the length or the height of the jetties, or their precise location or distance apart, but to submit a general plan of improvement by means of submerged jetties that shall have their crests, throughout those portions which cross the thread of the current, at a height corresponding to the least width of the gap between them, the objects sought by this method being to lessen the first cost of the jetties, and to obviate the necessity of their subsequent extension.

The foregoing discussion will be revised, if necessary, in a supplementary report, as soon as the actual velocities have been ascertained by observation, and the requisite borings have been made.

CONSTRUCTION AND ESTIMATES.

The jetties to which the following estimates apply are those last discussed, located on the lines CX′ and DY′, Plate I. The varying heights to which they rise above the bottom are shown by heavy parallel hatching in longitudinal sections CXX′ and DYY′, Plate II.

Their sea ends for a length of 3,000 feet on the north jetty and 3,500 feet on the south jetty have their crests at the level of half flood of spring-tides, or 3 feet above mean low-water.

The total length of the north jetty is 8,480 feet, and that of the south jetty 13,040 feet. These are theoretical lengths. In practice it will probably be found necessary to give some additional length. They are to consist of a superstructure of riprap stones with rather low side slopes resting on a mattress of fascines 2 feet thick.

The slope on the exterior faces of the jetties will be 1 upon 2 throughout their entire length. On the interior faces it will be 1 upon 1½, except on the sea ends, where, for a distance of about half a mile, it will be 1 upon 2.

For the north jetty the minimum width on top is 15 feet. This is in the lowest portion where it crosses Beach Channel. From that point outward, the width increases to 24 feet, which is adopted for that portion which rises above mean low-water level.

The south jetty has a minimum width of crest of 12 feet where it crosses the main channel, at depths varying from 10 to 15 feet below mean low-water. Thence outward the width increases to 24 feet for the highest part, as in the case of the north jetty.

It cannot perhaps be safely assumed that beds of clay which may be encountered near the surface are sufficiently firm to resist the weight of the works, without considerable subsidence. Where such beds, however, are overlaid by a thick stratum of sand, or a mixture of sand and shells, no great disturbance may be expected.

Where the jetties are constantly submerged, they will not exert a pressure upon the mattress foundation exceeding 91 pounds per square foot for every foot in height, to which must be added, where the work rises above low-water level, about 59 pounds more for each foot in height during the time they are out of water. This takes no account of any lateral distribution of weight, which must in a greater or less degree take place in riprap constructions.

There being only two points where the actual pressure upon the bottom will approach near to one ton per square foot, while it will generally fall below one-half ton, it is believed that no settlement or disturbance of a very serious character will be likely to take place. At the two points referred to, in the main channel, both weight and cost could be reduced by replacing a portion of the hearting of the jetty with mattresses similar to those used for the foundation, as shown in Fig. 2, Plate II, care being taken to keep the wood well inside the riprap, so that after the voids in the latter have become filled with sand, it would be safe from the ravages of worms. During the progress of work the voids could be filled at moderate cost by pumping sand from the bottom near by.

Riprap suitable for the entire work, except the facing of the sea ends of the jetties, can be procured for \$3.75 to \$4.00 per cubic yard, measured in the jetties. The stone for facing should be rather large, and will cost \$5.50 to \$6.00 per

cubic yard. The foundations of mattresses or poles, can be laid for about $1.00 per square yard.

Twenty to twenty-five per cent. would be a fair estimate for additional riprap, required to compensate for subsidence.

A liberal allowance of dredging and raking in the new channel, in material not susceptible of removal by the scour of the current, would be $150,000.

Due account being taken of contingencies, the total cost of both jetties may be stated at $1,500,000 to $1,800,000.

EXPLOSION OF A WESTERN RIVER STEAMER.

By JOHN W. HILL, M. E.

Written for Van Nostrand's Engineering Magazine.

On the night of May 17th, 1876, the steamer Pat Cleburne, of the Evansville, Cairo and Memphis Packet Company, a vessel plying between Evansville and Cairo on the Ohio river, exploded three of a battery of four boilers, completely wrecking the vessel and killing and injuring more than twenty people.

The steamer left Evansville on the afternoon of the fatal day, and between ten and eleven oclock P.M., made a landing at Shawneetown, several miles below the confluence of the Wabash and Ohio rivers : about one hour before midnight, the boat rounded out from this port and pursued her course down the Ohio. When within a distance of two and a half to three miles from Shawneetown, the steamer was hailed to come alongside by the Arkansas Belle, a vessel of the same line lying to at Coles, a landing said to be three to three and a quarter miles below Shawneetown.

The Cleburne steamed down to the Arkansas Belle, rounded in and drew up alongside. When she came abreast of the Belle, and about six feet separated therefrom, the port and two central boilers exploded with terrible violence, killing among others the master and chief engineer.

From the surviving officers of the wrecked steamer, and the officers of the Arkansas Belle, the following facts are obtained : The Cleburne was running with a pressure of one hundred and twenty-five pounds steam (considerably less than the U. S. certificate of inspection allowed) and blowing through the feed water heater at time of explosion—the furnace doors were opened to shorten the fires—the doctor (feed pump) was working at usual speed—the engines were stopped or slowed whilst rounding in. When the boats were nearly abreast the port engine bell rang to go ahead—the chief engineer who had previously hailed the officers of the Arkansas Belle from the engine room window, stepped back on the foot board—dropped the rods—opened the throttle, and the explosion promptly followed. The starboard boiler was uninjured except the breakage of connections, but after the explosion it was found rotated fore and aft on its seat. This boiler was shortened after the explosion, and set up on the steamer Idlewild for port duty. About fifteen months after the explosion occurred, the facts above were given to the writer, with instructions from the steamboat company to investigate the explosion and report upon the probable cause. No effort was spared by the officers of the company to arrive at the facts, and every facility was offered to make the inquiry as searching as the limited materials permitted.

According to the certificate of inspection, the machinery of the Pat Cleburne consisted of two non-condensing engines each $20'' \times 84''$ cylinder; steam was conveyed to these through 5″ copper pipes; the doctor drove two cold water pumps and two hot water pumps, each 5″ diam. $\times 12''$ stroke. The boilers, four in number, were of the return flue variety, each 24′ long 37″ diam. with 2—14″ flues, the clear space between flues, and between flues and shell was 3″. The shell courses were of $\frac{5}{16}''$ iron and the flues of $\frac{1}{4}''$ iron. All shell joints were single riveted. The after ends of the boiler were concave, and the mean length of flues about 22′

6″. Three boilers were furnished with free safety valves, and one boiler with a lock-up valve; each boiler had three Mississippi gauge cocks and a low water gauge; fusible plugs were inserted in the fire courses and after ends of flues of each boiler. The evaporation was collected in a large cylindrical steam drum lying athwartships and connected by 12″ legs to the second after course of boilers. The steam pipes, (two), connected with the steam drum, midway between the first and second legs and the third and fourth legs. Under the boilers, and directly opposite to the steam drum, lay the mud drum; this was connected to the boilers by 12″ legs. The hot water pumps delivered the feed through direct copper pipes to the mud drum.

The boilers were built in Cincinnati during the year 1870, and at time of explosion had been in use less than six years. According to the U. S. inspector's certificate, issued about five months previous to the disaster, the limit of working pressure was fixed at one hundred and forty pounds by gauge, and every detail of boilers and attachments complied with the U. S. Treasury regulations.

The exploded boilers were literally torn to fragments, and no portions of shells or flues were in existence at time the writer began the investigation. The fusible metal in the safety plugs was Banca tin, and when found, nearly all of these were melted out; but as the wreck burned to the water's edge, within a very few minutes after the explosion, the probability is that these plugs were melted out after, and not before, the explosion.

The officers in charge of the Pat Cleburne, were of the best on the lower Ohio, and the chief engineer was reputed without a superior in the management of steam boat machinery. After commencing the investigation, the following facts were obtained: from the master of the wharf boat at Shawneetown; that he was on the vessel, conversed with the engineer, and saw him test the water level in the boilers within fifteen minutes of the explosion: from the second engineer of the Cleburne who was asleep in the "Texas" when the boilers let go; that he was on the boiler deck within an hour of the explosion, and no known derangement of doctor or boilers existed, except a slight leak in the second or third roundabout joint upon the side of one of the central boilers: from the master of the Arkansas Belle, who was on the starboard guard of his vessel when the Cleburne rounded in; that the port wheel of the wrecked steamer made a revolution or partial revolution before the boilers let go; indicating that the cam rods had been dropped in gear, and the throttle opened to give steam to port engine; and that the piston had begun its stroke. By way of explanation it should be remarked; that when a river steamer is under way, and a necessity for stopping occurs, the throttle valve is but partially closed, the cam rods unhooked, and the valves set to blow through.

Thus the surplus steam, instead of wasting through the safety valves, is blown through the cylinder into the heater, and utilized to elevate the temperature of the feed water to the boilers.

The facts enumerated, from the surviving officers of the wrecked steamer, the officers of the Arkansas Belle, the superintendent of the steamboat company, and the inspection certificate, were the basis of examination. In the West, and, so far as the writer is aware, in the East also, when a steam boiler explosion occurs, the first step is to secure a scape goat to carry the burden of blame: if the engineer in charge survives the disaster, he is usually "honored" with the appointment; if he is killed, sympathy overbalances public prejudice, and the excoriation is discharged in some other direction.

In the case of the Cleburne, however, the very excellent discipline maintained by the steamboat company, together with the known qualifications of the officers of the steamer, and especially the fact that the unfortunate chief engineer was above suspicion of incapacity or negligence, had an effect to stultify wild speculation on the cause of the explosion.

The facts obtained support the following assumptions:

First. No known defect existed in the boilers or feed water machinery of the Cleburne when she rounded out from Shawneetown.

Second. Upon leaving Shawneetown,

the Cleburne steamed up to the usual running pressure; and the signal to come alongside the Arkansas Belle was unexpected: (shortening fires and blowing off were resorted to, to control within safe limits, the steam pressure).

Third. No evidence of danger on the Cleburne had presented before coming alongside the Arkansas Belle: (the firemen having opened the furnace doors and walked out on the port guards, and when nearly abreast, the chief engineer of the Cleburne came to the engine room window and cheerily hailed the officers of the Belle).

Was low water the cause of the explosion? When the Cleburne left Shawneetown, we are informed, the usual level of water obtained in all the boilers; from this port to the meeting with the Arkansas Belle, not more than fifteen minutes elapsed, during which time no steam was blown off save through the engines. Neglecting the leak, which we are informed was insignificant, then the reduction of water level in the boilers (assuming a total failure upon the part of the feed pumps to supply during the interval) would be that due to evaporation alone.

The aggregate heating surface to each boiler is taken as 325 superficial feet, and maximum evaporation per hour per square foot of heating surface as *six pounds;* and maximum evaporation per boiler for fifteen minutes $\frac{325 \times 6}{4} = 487.5$ pounds, or 8.75 cubic feet at temperature of 353 Fahr. This evaporation corresponds to a reduction of water level of less than one and one half inches; the usual level of water over the flues was *four to five inches.* All evidence went to prove that no failure to supply the boilers occurred prior to the explosion; the doctor was simply a small beam engine, with a plain slide valve; driving four pumps—two piston pumps for cold water, and two plunger pumps for hot water. The cold and hot water pumps were in duplicate; in the event of failure of one pump, the other was of sufficient capacity to supply the boilers. As against a sensible reduction of water level in the boilers during the fifteen minutes run—whether from failure of the "doctor" to supply, or from any other cause—the frequent examination of the water level is "second nature" to the experienced engineers; hence the writer is unwilling to believe that a person of the experience and known capacity of the first engineer of the Cleburne, with the doctor and water gauges directly under his eye, would fail to detect a fault in the working of the one, or test the other, during the run from Shawneetown to the meeting with the Arkansas Belle. Assuming, however, that no water was supplied to the boilers after leaving Shawneetown, then the reduction of water level, by evaporation alone, could not have been sufficient to uncover the flues. In fact, the water over the flues at the time of explosion could not have been less than *two and a half to three inches*, quite enough for all purposes of safety. The blow off, or mud valves, as they are termed on the Western rivers, closed under pressure, and could have been opened only by manual effort; no evidence offered to show that these valves either leaked or were opened, hence it is reasonable to conclude that no water left the boilers by this outlet.

The leak, already noted in one of the central boilers, was in a roundabout seam forward of the bridge wall, and had been noted from time to time by the chief engineer for several days. From the statements of the colored firemen who survived the disaster, this leak was due to defective caulking of the overlap, and was no evidence of weakness in the boiler. (Boilers frequently leak at the riveted joints, and a new boiler absolutely free from seam leaks is a rare circumstance. But a leaking joint in an otherwise sound boiler, is no cause for alarm; the caulking that makes a joint tight under pressure adds nothing to the pronounced strength of a boiler, and the only effect of a seam leak would be to impair the economy of performance, and impose an increased duty on the feed pump). This leak was in plain view from the front of the boilers, and could be seen by the fireman every time the furnace doors were opened; these *were* opened and fires banked within two to three minutes of the time of explosion, and it is not very probable that an increase had taken place in the leak, without the fireman observing it. The after end of each flue contained a fusible plug, and at this point the hot gas passing forward through the flue is at the maxi-

mum temperature; the plugs were inserted in the crowns of the flues, where the collection of scale is a slow process; and it is very unlikely that of eight independent plugs supposed to be in the same horizontal plane, not one would have melted and given an alarm, had the water level fallen below the crowns of the flues before the explosion.

When found, the fusible metal in some of these plugs was melted out, but the fragments of the boilers lay on the wreck of the vessel while it burned; and there can be no doubt that these plugs were fused in the raging fire which promptly followed the explosion.

When the boilers of the Cleburne ruptured the fusible plugs were intact; for the peculiar whistling sound, as the steam and water rushes through the orifice in the plug, could not have escaped the attention of the engineers and firemen on watch. Let it be supposed, however, that the water level had fallen so low as to uncover the crowns of the flues and melt the metal in the plugs (as it has been asserted in connection with this disaster); would this have been a sufficient cause for the explosion? Evidently not, if fusible plugs are possessed of any virtue: for the plug, or rather the core of the plug, is not supposed to melt until the crown of the flue is uncovered, and heated to a temperature of 420° Fahr.; and as the fusing and blowing out of the core is only intended as a timely warning against danger, it follows that the melting of these plugs would be no argument in behalf of low water as the cause of the explosion. As a further argument against low water as the cause of the explosion on the Cleburne: in rounding in the vessel listed to port, thus elevating the boilers to starboard, and low water, if it obtained at all, obtained to the greatest extent in the starboard boiler; *this boiler was wholly uninjured,* and is now in daily use on another vessel of the same line.

Without discussing "low water" as a probable cause of explosion in boilers of this class, set and fired as were these boilers; the writer would suggest that low water was *not* the cause of explosion in this instance, and all the facts appear to sustain this view.

Examining as to the probability of explosion by defects of materials, improper construction or deterioration from use; we find that the boilers (four in number) were all made at the same time, of the same brands of iron, of precisely the same dimensions, and had been worked together for six years, under like conditions. During this time they had been inspected many times, at different ports, by different inspectors, and had defects of materials existed, they would have, in all probability, been detected before the explosion. Whilst there is no doubt of the reckless manner in which boilers are put together being a fruitful source of explosions, no evidence was offered to show that the boilers of the Cleburne were not well built; and if the surviving boiler is an index of the workmanship, they were in this respect considerably above the average. The precise condition of the boilers at time of explosion is not known, except they had been carefully washed out a few days before. But as the boilers had always worked together, and resisted the same strains, and destructive action of fire and water, it is reasonable to presume that the unexploded starboard boiler was no better than the others. This boiler was opened after the accident, and a careful examination revealed no special or dangerous deterioration.

It has been suggested that over-pressure was the cause of the explosion. Under the certificate of inspection the boilers of the Cleburne were limited to 140 pounds by the gauge; but at the time of the explosion, or more correctly a few minutes before, the pressure was 125 pounds; the last inspection was made less than five months prior to the accident: and under the U. S. Treasury regulations the working pressure is taken at one-sixth the tensile strength of plates, and the proof pressure at one and one-half times the working pressure: hence, the proof pressure of these boilers, according to the inspector's certificate, was 210 pounds. It is scarcely possible that their strength was diminished *forty per cent.* during the last five months of use. It might be supposed that the steam guages were unreliable, and failed to indicate the true pressure, which was considerably higher than indicated by the gauge. But from all the evidence furnished the writer, the pressure that ruptured the boilers was less than that at

which the safety valves were set to blow: this was one hundred and forty pounds, and the valves were frequently eased on their seats to insure prompt action.

As the writer understands the term, over-pressure was not the cause of the explosion; that the strains at time of rupture were in excess of the strength of the boilers is evident; but that the steam pressure steadily increased until the strains were in excess of the resisting powers of the boilers is scarcely possible, in view of the testimony of the engineer's assistant, and the surviving firemen, that the pressure was, within two or three minutes of the explosion, one hundred and twenty five pounds, with furnace doors open and fires banked.

Without adverting to other improbable theories of explosion, as applied to the ill-fated Cleburne, the writer will endeavor to establish what, in his opinion, was the cause, in accordance with the facts related. When the steamer left Shawneetown, the "regimen" of the boiler was calculated for a long run. The boiler capacity of river steamers to reduce dead load is usually a minimum, and active firing is frequently resorted to, to maintain a running pressure. But the flow of steam out of the boilers, and the flow of water in, is usually correspondingly uniform, and no evil effects are liable to follow forced firing.

When the Cleburne was hailed by the Arkansas Belle to come alongside, the condition of fires and steam pressure were unfavorable to a stop, and the furnace doors were opened and fires banked. But the time elapsing from receiving the signal, to its coming alongside the Bell, could not have been more than four or five minutes; and the time elapsing between the banking of fires and the explosion not more than two or three minutes. Upon reception of the signal to stop, the engines of the Cleburne were slowed; and whilst rounding in, the use of the wheels would be irregular, and chiefly confined to the port wheel; and when the vessels were nearly abreast the port wheel was stopped entirely for an interval of several seconds, during which time the vessel drove on by momentum. In warping in a spurt from the port wheel was necessary to avoid a bow collision—the port engine was started—when the explosion of the port and two central boilers almost instantly followed. Previous to the rupture of the boilers the steam and water had been heated to a temperature of 353° Fahr., and the iron of the under courses and flues to a temperature somewhat in excess of this. The walls of the furnaces were glowing from the active firing and the circulation sufficient to prevent overheating of iron or water; directly the speed of engines was slowed the rapid ebullition in the boilers was checked by the increase of pressure, and whilst the flow of feed water into the boiler may have been unchanged, the flow of steam out of the boiler, for a brief period of time ceased nearly, if not quite altogether. The natural result of this would be to reduce the circulation from previous activity to a state of partial quiescence, and localize the heat. The capacity of the water to receive heat and vaporize would be temporarily diminished, and the iron of the under courses quickly heated to a temperature sufficient to repel the superincumbent water from the plates. This temperature is variously estimated from 380° to 430° Fahr., hence we accept a mean of 405° as applicable to the iron in the boilers of the Cleburne; then an addition of 50° Fahr. would anticipate the condition of plates necessary to perfect repulsion. The previous active fires in the furnaces; the unexpected stop; the brief interval between receiving the signal to stop, and coming alongside the Arkansas Belle, were conditions favorable to the repellant action. Without entering into a discussion of the theory of repulsion, the *rationale* of which is well understood by steam engineers, the writer would suggest that directly the repellant action occurs, the iron of the boiler instead of acting as a vehicle of transmission of heat, becomes as it were a receiver of heat, and the temperature of the plates is rapidly augmented by the impinging hot gas. It is assumed, in the case of the Cleburne, that the repellant action occurred at a time when the engines were stopped, and the flow of steam from the boiler at a minimum, or checked entirely. At this time the circulation was sluggish, and ebullition slow and irregular. Meanwhile the storing up of heat in the iron of the shell went on until an unknown tempera-

ture was attained; no increase of pressure was indicated by the gauge, and no appreciable variation was noted in the water level; the fires were banked and furnace doors open, and so far as the engineer could qualify, every precaution had been taken to avoid danger. The port engine bell was rung to "go ahead"; the engineer dropped the cam rods, opened the throttle, and the piston began its stroke; the flow of steam to the engine reduced the pressure in the steam drum and steam room of the boilers, sensible heat became latent with a quick vaporization of a portion of the water. The reduction of temperature of the water, and the return to the highly heated plates, were instantly followed by the production of a comparatively large volume of steam which, in seeking to escape to the surface and vaporize, carried the water with it and delivered it as a projectile against the limiting surfaces of the boilers.

THE HYDROLOGY OF THE MISSISSIPPI RIVER.

REVIEW OF REPORT BY HUMPHREYS AND ABBOT.

By JAMES B. EADS, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

As the report on the Mississippi river made by Generals Humphreys and Abbot in 1861, has been recently republished by the Government, and as it contains certain grave errors touching the navigation of the river and the reclamation of its alluvial basin, I desire to expose them, and to show that many of the statements made by the authors of the report are not sustained by the facts to which they refer. If the reader will follow me attentively, I promise to demonstrate, to his entire satisfaction, the utter absurdity of these statements.*

It does not interest the general public to know whether the quantity of sediment carried by the water of the river, is adjusted by the rate of its current or not; or whether the real bed on which rest its moving sand bars, is of recent, or of ancient geologic stratification, or whether it wears rapidly or slowly under the action of its current, unless these questions are known to have an important bearing upon the commercial and agricultural prosperity of the Valley of the Mississippi. When this is known to be the fact, the scientific interest in them is completely dwarfed by the overwhelming practical bearing which they have upon great national interests. It is for this reason that I select your widely circulated journal as the surest means of thoroughly reaching the intelligent readers of the country, rather than to attempt, through the less extensively circulated records of any of the scientific bodies of which I am a member, an exposition of the dangerous errors advanced by Humphreys and Abbot.

THE RELATION BETWEEN THE CURRENT AND THE SUSPENDED SEDIMENT.

In 1874, I stated in a pamphlet, that the chief portion of the sediment discharged by the river into the Gulf is carried in suspension, and "that the amount of this matter, and the size and weight of the particles which the stream is enabled to hold up and carry forward, depend wholly upon the rapidity of the stream, modified, however, by its depth."

General Humphreys immediately afterwards said,* this statement is "in direct conflict with the results of long continued measurements made upon the quantity of earthy matter held in sus-

* In 1874 I proved to the satisfaction of the Congress of the United States, *by the data contained in this report*, that the theory of bar formation at the mouth of the Mississippi advanced by its authors, was totally wrong, and thus secured for the river an unobstructed and open outlet to the sea through the bar at South pass. It is needless to say that the predictions made by General Humphreys regarding the re-formation of the bar in advance of the jetties, have not been realized. This paper is intended to expose other erroneous theories advanced in the same report, and which stand in the way of a correct system of improvement of the entire river, and which are declared to be conclusively demonstrated by patient scientific and experimental investigation.

* See Executive Document 220, 43rd Congress. Also last edition of Report on the Mississippi River, page 674

pension by the Mississippi river at Carrollton (near New Orleans), and at Columbus (twenty miles below the mouth of the Ohio), one of the chief objects of which was to determine this very question, whether any relation existed between the velocity and quantity of earthy matter held in suspension. These results prove that the greatest velocity does not correspond to the greatest quantity of earthy matter held in suspension; on the contrary, at the time of the greatest velocity of current at Carrollton, the river held in suspension but little more sediment per cubic foot than when the velocity was least."*

These results when correctly interpreted prove precisely the contrary of the idea here conveyed by General Humphreys. He says that my statement is in direct conflict with them, and then proceeds in effect to tell us, that there is no relation between the velocity of the current and the sediment carried in *a cubic foot of water*, which is a very different thing, as the reader will soon see.

Gen'l Humphreys evidently means to convey the idea that the most rapid current carries but little more sediment than the least, when in fact by his own tables, it carried more than twenty times as much as the least current at Carrollton, and more than forty times as much at Columbus.

They use the terms "a cubic foot of water" and "the current," as expressions having one and the same meaning; whereas the current per second represents the force due not to *one* only, but to an immense number of cubic feet of water passing, in each second of time, by the place where the current is measured; and it is the total sediment suspended in this immense number of cubic feet that should be compared with the rate of the current per second.

One of the chief objects, we are told, was to determine "whether any relation existed between the velocity and the quantity of earthy matter held in suspension." In what? *In a cubic foot* of water, or in the whole river? Certainly in the latter, for the quantity in a cubic foot is of no practical value except as a means to determine its relation to the whole quantity.

They pushed their investigations however only to the extent of trying to find the relation between the current per second and the sediment in a cubic foot. Failing to discover this, for they proceeded no farther, and supposing that they had solved a problem in which they had neglected two essential elements, they announced their astonishing discovery that no relation whatever exists between the rate of current and the quantity of sediment suspended by it; or, in plainer English, between *cause* and *effect.*

This question could only be solved by bringing the elements of *space* and *time* into the computation for the sediment, just as they are brought into the current measurement, that is, by comparing the mean velocity *per second* with the total weight of sediment suspended per second. They, however, compared the mean velocity in every instance with the mean sediment contained in but a single unit of the river's volume, and they not only published the results of this meaningless comparison, as *a proof* that there is no relation between the rate of current and the quantity of sediment, but they have founded unsound theories upon this error, and have officially advised a dangerous system of river treatment based upon it.

I will now show *why* they should have compared the current, per second, with the total quantity of sediment passing by their point of observation in the same unit of time. To make this easily understood by the general public, compels me to state much that will be commonplace to the scientific reader.

Motion cannot occur in matter without an expenditure of force. The transportation of sedimentary matter in water, can, therefore, only result from an expenditure of force, and only by supplying the requisite amount of force, as it becomes exhausted, can these matters be lifted up and kept from falling back to the river bottom. Being heavier than water, it is just as impossible to uphold them in it without force, as it is to raise chaff in the air, or sand and dust in a whirlwind without it. The current caused by the river flowing from a higher to a lower level supplies this force.

* See last edition Mississippi River Report, page 138, and Appendix D.

The investigation of all questions relating to the expenditure of force, belongs to that branch of science called *Dynamics*, and in all such problems, whether they relate to a treadmill, or a steam engine; to the tiniest ripple, or the grandest river ; to a grain of sand as it moves onward to the sea, or to the most majestic planet that pursues its pathway in the heavens, each and all involve the consideration of four distinct elements in their solution; and unless each one of these be duly considered no assumed solution of the question can be worth the paper on which it is made, except perhaps to "point a moral."

These elements are, first, *force*, second, *matter*, third, *space*, and fourth, *time*. Gravity and pressure are examples of the first element, and one of these, gravity, constitutes the first factor in our problem. The term volume, or mass, is used to indicate the quantity of the second element, while the term speed or velocity embraces the last two elements, and indicates the space through which the force acts, and the time involved in the action.

The amount of force expended can only be ascertained by knowing the weight or pressure exerted; the space through which it acts, and the time occupied in such action.

The relation of these four elements to each other may be illustrated by suspending two equal weights from the ends of a lever with equal arms, supported at its middle. While at rest they present simply a statical problem, in which force, matter and space alone, are involved. When in motion, however, the other element, time, necessarily enters into the problem. If motion be imparted to the weights, and one sinks towards the earth, the other will be raised through a space exactly equal to that through which the other falls, and in the same time in which the other falls. The velocity and mass of the descending weight gives the measure of the force expended. This force can only be determined by these three elements, first, the weight, second, the space through which it moves, and, third, the time required to move through the space. *The work done* consists in its raising the other *weight* through the same *space*, and in the same *time*. Therefore the force expended will be precisely the same that is required to raise the same weight, through the same space, in the same time. Hence it is an axiom that "The work done must bear an invariable quantitative relation to the amount of force expended."*

If the point of support of the lever be moved from the center toward one weight until the latter will balance one only half as heavy, it will then be found that when the large weight descends in one unit of time through a certain space, the small weight will have been raised through twice that space in the same unit of time, and therefore, the small one will have moved with twice the velocity. Hence, if we raise a weight through twice the space, in the same time, we must either double the force, or lift but one-half the weight. If we reverse the motion of the weights, and the smaller one descends, we illustrate the fact that by doubling the velocity, half the force will lift twice the weight.

In the steam engine the pressure of the steam takes the place of the pressure or force exerted by gravity. To determine the power of the engine we must have, first, the pressure upon the piston, second, the space through which it moves, and third, the time occupied in its movement. If the same pressure be maintained per square inch in each of two cylinders, and the velocity of the piston in one be twice as great as in the other, the more rapid one will develop as much power as the other with half the area of piston ; just as half the weight on the doubled length of the lever arm can develop the same amount of force as the whole weight, because it will then move with twice the velocity.

The power of a waterfall is estimated by the same three elements. The weight of the water falling in one minute of time and the number of feet of space through which it falls in the time, are multiplied together, and when divided by 33,000 foot pounds, the quotient will represent the horse power of the waterfall or head of water; a horse being supposed to be able to raise 33,000 pounds, one foot high, in a minute of time.

It is unnecessary to point out by farther illustration the fact that these three elements, matter, space, and time, are inseparably related in any investigation to determine either the amount of force

* Mayer.

expended or of work done. I need only add that no matter how intricate the machinery, or secret the medium through which moving bodies transmit their forces, these three elements are as absolutely requisite to determine the amount of the force expended, or the work done, as the depth, width, and length of a rectangular box are, to determine its capacity ; and no matter how occult may be the relation between them, it is nevertheless as indissoluble, complete and perfect as in this simple illustration.

The work performed is precisely equal to the force expended when operating any steam, water or other motor, but the work *practically* considered is of two kinds: one of which may be called profitable or visible work, and the other unprofitable or invisible work, the latter being that part of the force which is expended in overcoming friction, back pressure, atmospheric resistance, radiation, &c.

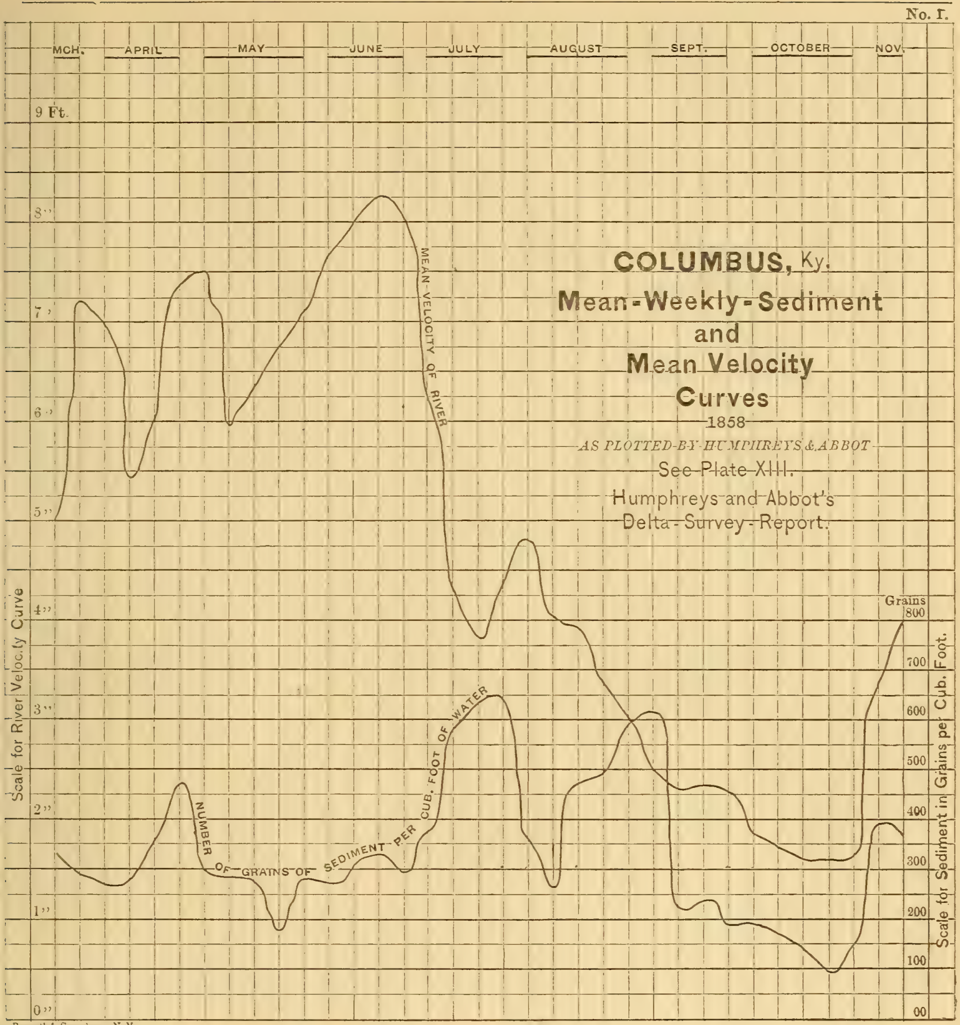
The work done by the force which the Mississippi River expends we may, for the sake of illustration, also divide into two kinds, and call the first, invisible, or unprofitable work, among which we may class the overcoming of the friction of the bed of the stream, the friction among the particles of water, the resistance due to the irregularities and bends in the channel, the atmosphere, &c., leaving to be considered, as the visible or profitable work, the transportation of its immense burden of sediment. The problem we are considering and which these gentlemen claim to have determined, is the relation which the current, or force, expended by the river bears to this great burden of earthy matter.

Let us suppose a railway train be used in transporting grain, and that we wish to determine the relation between the force (or coal) expended, and the quantity of grain carried ; we would carefully ascertain the total coal burned in some definite *time*, for instance, in one hour, and also the *total weight* of the grain carried in that hour, and likewise the *space* over which it was carried during that hour. We would then be able, by comparing the total coal with the total weight, to declare absolutely that so much coal or force expended, was equal to the carrying of so much grain a certain distance in one hour, and the relation between the force expended and the work done would be so expressed.

In such investigation we would have 1st, force (the coal) ; 2d, matter (the load of grain); 3d, space (the distance the load is carried); and 4th, time (the hour during which it was carried). By repeatthe measurements under similar conditions, but with different quantities of time, space and weight, this relation between force and work would appear constant and inseparable. An instructive comparison could only be made, either between the *totals* of the force and work, or between their respective *units*, and in either case *time* and *space* would be indispensable elements to be considered. But if the total coal be only compared with the weight of a *single bushel* of the grain, and no note be taken of the *space* through which it was carried, nor of the total number of other bushels that were carried in the same *time*, the comparison would have no significance whatever. A diagram to represent such a comparison, as an ultimate solution of the question, would not only be meaningless but absurd; yet it would be precisely similar in principle to the diagrams which Humphreys and Abbot represent on plates XII and XIII of their report, where the current per second is contrasted with the sediment found in a single cubic foot of water. An accurate fac simile of plate XIII is herewith shown. (See diagram No. 1.)

If the mean current at Columbus was six feet per second, an entire section of the river six feet long must have moved at that place and time through the space of six feet, and the force expended was, therefore, the entire force due to the motion of this whole section during that second.

The mean current given in feet per second, is, therefore, an exponent of this whole force, and if it be six feet per second, it can only be intelligently compared with the total sediment carried in an entire section of the river six feet long, and not with that in a single cubic foot. If we multiply the cross section of the river in square feet by the current in lineal feet per second, the product would be the number of cubic feet in the section, and these multiplied by the number of grains of sediment in one foot,



Russell & Struthers, N.Y.

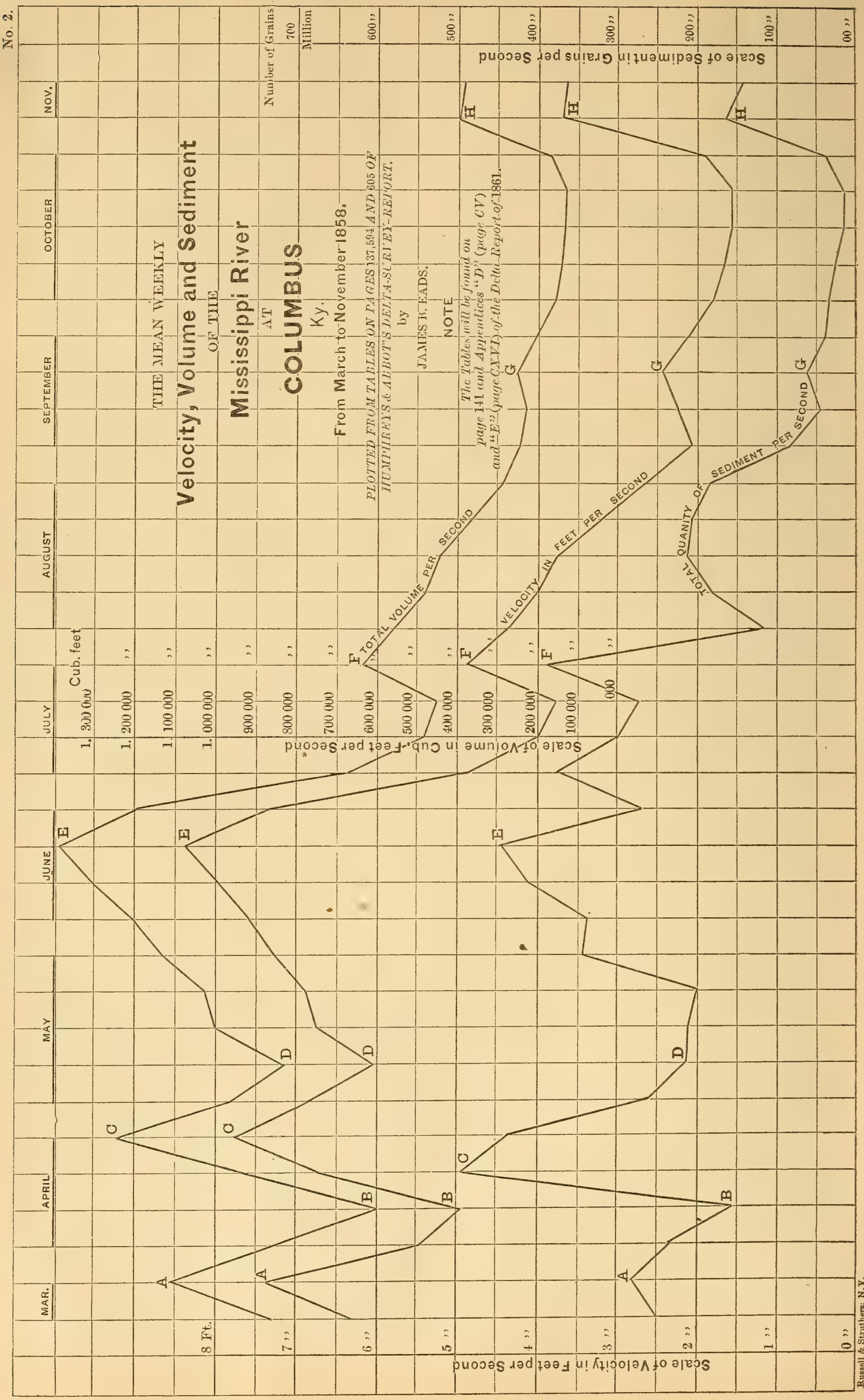
would give the proper amount for comparison with the current.

As the work done and the force expended must be precisely equal, it is evident that the three elements, namely, *matter*, *space and time*, are as necessary to determine the amount of *work done*, as they are to determine the amount of force expended.

In appendix D of their report will be found tables, giving in cubic feet, the daily volume of water flowing per second, by the velocity base or point where these measurements were made: These quantities were ascertained by multiplying the cross section of the stream in square feet each day with the mean velocity of the current at the time, in linear feet per second. The two absent dynamic elements, namely, *time*, (one second), and *space*, (the linear feet the river moved in one second), are thus included in these tables. By taking the average or mean weekly discharge in these tables, and multiplying it with the mean sediment in grains found each week in one cubic foot of water, given in the tables, we get the proper quantities of sediment to compare with the average rate of current per second.

Diagram No. 2 is prepared in this manner from precisely the same data which Humphrey's and Abbot used to prepare Diagram No. 1, except that in mine the absent elements, *space* and *time*, have been included as above explained. A

No. 2.


THE MEAN WEEKLY
Velocity, Volume and Sediment
OF THE
Mississippi River
AT
COLUMBUS
Ky.
From March to November 1858.
PLOTTED FROM TABLES ON PAGES 137, 594 AND 605 OF
HUMPHREYS & ABBOT'S DELTA-SURVEY-REPORT.
by
JAMES B. EADS.
NOTE
The Tables will be found on
page 141 and Appendices "D" (page CV)
and "E" (page CXVI) of the Delta Report of 1861.
MAR.
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOV.
TOTAL VOLUME PER SECOND
VELOCITY IN FEET PER SECOND
TOTAL QUANITY OF SEDIMENT PER SECOND
Scale of Volume in Cub. Feet per Second
Scale of Velocity in Feet per Second
Scale of Sediment in Grains per Second
Number of Grains
Million
Cub. feet
Russell & Struthers, N.Y.

third line is shown on my diagram which gives the mean weekly volume of discharge, by which the total weekly mean of sediment was ascertained.

If the relation between the current velocity and the quantity of sediment does not exist, as Humphreys and Abbot assure us, no correspondence or synchronism could be graphically shown between them on diagram No. 2 by any possible scientific analysis to which these data can be subjected. By their diagrams, none whatever is shown, because of their error.

An inspection of diagram No. 2 proves the existence of this relation in a way that admits of no dispute, and shows how remarkably sensitive the sediment is to any change of velocity in the current. This is particularly noticeable at each period when the current began to decline. The river rose and fell six times at Columbus while the observations were being made. These periods are indicated by the letters A, C, E, F, G, and H. The loss in velocity at each of these six periods, during the eight months, is invariably and *immediately* marked by a corresponding reduction in the quantity of sediment. No one can look at these two diagrams, made from the same tables and to determine the same question, without feeling assured that

"Some one has blundered."

A diagram made in the same manner from the Carrollton observations will show an equally striking evidence of the intimate relation between the rate of current and the quantity of sediment, which has been so persistently and dogmatically disputed.

The error made by Humphreys and Abbot when investigating the results of their experiments at Columbus and Carrollton, consists in supposing they were comparing a definite exponent of the *force* with a corresponding exponent of the *work*, when, in fact, the elements of *space and time* were wholly absent in the exponent of the work; and not only were these neglected, *but only one single unit of the third element of the work* was taken as the corresponding exponent to compare with the force.

Suppose we should attempt to show the relation between a certain quantity of grain, and the capacity of a rectangular box which it had exactly filled. Having ascertained the number of cubic inches of the grain, what relation could we hope to show between this quantity and the capacity of the box, if we compared it with only one single inch of the length of its bottom? Not only would we be ignoring the total length of the box, but we would also be neglecting the two other factors of the problem, namely, its width and its depth, and the comparison, therefore, would be utterly unintelligible. Such a mistake would be inexcusable in one who had barely entered on the threshold of geometry. The mistake made by Humphreys and Abbot is similar to this, and it is one equally unpardonable even in the merest tyro in the science of dynamics. Yet, relying solely upon this method of investigation, the Chief of Engineers of the United States army, to defeat the adoption of the present system of improvement at the mouth of the Mississippi river, actually prepared a letter which was read in the House of Representatives in 1874, and which referred to the subject we are discussing in the following language: "It is probably unnecessary for me to say here that, the statements which Mr. Eads has made in the pamphlets he has published concerning the conditions existing in the Mississippi river and at its mouth are the mere revival of old assumptions, which experimental investigation has long since shown to be utterly unfounded in fact."

Having clearly explained how their defective knowledge of the principles of dynamics led them astray, and having proved by their own testimony that they are clearly in error, let us now see to what absurd conclusions their unfortunate mistake carried them.

Referring to their experiments at Columbus and Carrollton they say on page 135: "An inspection of the preceding table must convince any one that the Mississippi water is undercharged with sediment, even in the low-water stage. A most important practical deduction may be drawn from this fact, namely the error of the popular idea that a slight artificial retardation of the current, that caused by a crevasse for instance, must produce a deposit in the channel of the river below it."

On page 417 this undercharged theory is repeated, as follows:

"A glance at the two diagrams is sufficient to demonstrate the falsity of the assumption, that Mississippi water is always charged with sediment to the maximum capacity allowed by its velocity."

Having exploded the "error of the popular idea" that cause and effect are related, we need not be surprised at this *undercharged theory*. And although we may have supposed that matter cannot move independently of law, and that neither an atom nor an avalanche can stir except in strict obedience to ordinances more fixed than those which swayed the Medes and Persians, we must be prepared to believe that the sediment of the Mississippi is an exception to this rule, for, having proved conclusively that its water is always undercharged, we are gravely assured on page 135, "If the water be undercharged, the distribution of sediment will follow no law, the amount at any point being fixed by the accidental circumstances of whirls, boils, &c." With such astonishing declarations as these, the reader will be partially prepared for the no less wonderful announcement that as the sediment will follow no law, the feeblest current can carry just as much of it as the most rapid current.

This statement will be found on page 684 of the last edition. It is as follows:

"In fine, these measurements upon the quantity of earthy matter, suspended in the Mississippi river, show that at no time has the water been so heavily charged with it that the current could not carry it along in suspension to the same extent as it did when the quantity of earthy matter was least; and they further show that *the current* of the Mississippi river, when most feeble, can carry in suspension the greatest quantity of suspended earthy matter found in it, to the same extent that it can carry the least quantity found in it."

I know of but one other statement concerning the wonders of this river that can compare with this one. In the last eighty years several cut-offs have occurred below the mouth of the Ohio, by which the channel was shortened about seventy miles. Based upon this fact, a distinguished writer has published the startling prediction that within a few centuries, two cities on the river, (Cairo and New Orleans) although now distant from each other one thousand miles, must, by this shortening process, inevitably be drawn together! By an inverse method of reasoning on these facts, he arrives at the interesting conclusion, that in some remote geologic period the Mississippi extended to Cuba! *

When pursuing a different line of investigation, distinguished engineers arrive at the equally astonishing conclusion, that the current of the Mississippi when most feeble can carry as much sediment as it can when most rapid, we may from the standpoint of common sense, safely assume that while the deductions, in each case, rest upon facts, the conclusions in both were arrived at by defective methods of scientific investigation.

If we examine these Carrollton and Columbus experiments we do not find this surprising statement about the power of feeble currents verified.

In the quotation, I have italicised the words "the current," to attract attention to the fact that no distinction is made between what *the current* carried and what *a cubic foot* of water carried. Diagram No. 2 shows what the current carried, while diagram No. 1 shows what was carried in *a cubic foot*. The one emphatically disproves this absurd statement, while the other furnishes no ground whatever for making it, because it conveys no idea at all of the relation between the current and the sediment.

At Columbus, the most feeble current carried but ten million grains of sediment per second, while during the third week in April, when the current was about four times as rapid, it carried 480 million grains, *or forty-eight times as much* as "when the current was most feeble." At Carrollton the current was most feeble in November, being but little more than a foot and a half per second, and then it carried less than 22 million grains, while in June, when the current was nearly three times as rapid, it carried 500 million grains, *or nearly twenty-three times as much* as when it was most feeble!

Dr. G. Hagen, Director General of

* Mark Twain.

Public Works in Prussia, and one of the most eminent engineers in Europe, in a recent criticism upon Humphreys and Abbot's theory regarding the distribution of velocity in flowing water, says :

"The young student of hydraulics is sometimes compelled to accept certain theorems as true and proven which, to say the least, are still doubtful; but he has as yet never been expected to receive devoutly a demonstration like this, and to regard it as a progress of science." This comment seems peculiarly applicable, likewise, to their conclusions regarding the relation between the current and the suspended sediment."

On the same page of their report from which the preceding remarkable extract is taken, is the following:

"This proposition, therefore, respecting certain velocities of current always carrying certain fixed quantities of earthy matter, and always adjusting those quantities according to its own variations of strength, is so entirely disapproved by facts that it will not be considered again."

In view of the fact that their own tables prove the utter fallacy of this statement, it is amusing to see the satisfaction with which it seems to be uttered.

It will be observed that all of these mistaken conclusions rest upon the assumption that the sediment found in *a cubic foot* of water, moving at different velocities, was a correct exponent of the ratio between the speed of the river and the burden it carried.

After referring to plates XII and XIII to prove that "the river is never charged to its maximum capacity of suspension" they declare (page 417)—"Hence if enough water had been taken from the river at the date of those floods (1851 and 1858) to reduce its velocity nearly to that of the lowest stage, no deposit in its channel could have occurred."

The highest velocity at Carrollton was 6.16 feet per second, and the sediment was then only 252 grains per cubic foot. In September the current had declined to 2.44 feet per second, while the sediment was 268 grains per cubic foot. These quantities were doubtless in view when the above declaration was made, because, as far as their "experimental investigation" had advanced it showed that a current less than 2½ feet per second actually carried more sediment *per cubic foot* than a current of over 6 feet per second. But the high current carried 280 million grains per second, because 1,140,000 cubic feet of water were then passing per second, while the low current carried but 100 million grains per second, or but little more than one-third as much; because the volume of water was then only 375,000 cubic feet per second.

At Columbus, 320 grains per cubic foot were carried with the highest current, 8¼ feet per second, in June, while 608 grains were carried in August with a current of 2.57 feet per second.

But when we bring in the absent dynamic elements of *space* and *time*, and ascertain by them the total quantity of work really done by the current at Columbus, we find that the river carried 444 million grains per second with the high current, and only 180 millions with the low current, because its volume of discharge with the high current was nearly 1,400,000 cubic feet per second, and only 280,000 with the low current. Hence it is simply impossible that the high water burden can be carried with the low rate of velocity without deposition occurring.

We learn from the illustration of the lever and weights, that the same force can only raise half the weight if it raise it to double the height in the same time. Hence we should not expect to find as much sediment *per cubic foot* in deep water, with a given velocity, as in shoal water. This fact will account for the quantity being greater per cubic foot in some of the measurements when the current was moderate, than when it was most rapid. The greater distance between the sediment and velocity lines during the first four months on diagram No. 2 is very marked. These were the high water months and the modifying effect of the depth of the stream on its power to suspend the sediment is clearly shown by the greater distance between these lines.

The depths as well as the velocities are usually greatest during floods. When the current was 8.25 feet per second, the depth at Columbus was 27 feet greater than when it was 2,57 feet per second, yet the tables show that the low current supported a greater quantity *per cubic*

foot than the higher velocity, because, *first*, it did not raise it so high above the bottom; and, *second*, because the river was falling. As many hours are necessary, even in still water, for all the sediment to fall, it must be evident that when the river is falling and the current diminishing, the water will have a greater amount in suspension than is then due to the velocity; and that when it is rising and the current increasing, it will then have less in suspension than the velocity would indicate. Therefore, the quantity found at a low velocity, if the river be falling rapidly, may be much greater *per cubic foot* of water, not only because of less depth, but also because of a diminishing velocity. The diagram (No. 2) shows that both causes operated to induce this great charge of 608 grains per cubic foot with this low rate of current.

The tables of sediment show also that the lower part of the water is somewhat more largely charged with sediment than the upper. This would act as an additional cause for the low water currents showing a larger ratio of sediment, particularly when the river has been falling some time. When it first begins to lose its high velocity, the largest particles, such as gravel, (which is undoubtedly carried in *suspension* with the higher velocities, in moderate depths) and coarse sand are first deposited. These fall rapidly, while the smaller particles require more time for settlement, according to their magnitudes and specific gravities. Fine particles of sand, which require the microscope to make them visible remain a long time suspended, and are carried with very low velocities. The material which forms blue and other clays is deposited during periods of low water and sluggish currents, and microscopic sand is always present in these alluvions. Many strata of hard blue clay were encountered by the piers of the St. Louis Bridge, when sinking them through the 80 feet of deposit overlying the limestone bed of the river. None of these were more than six or eight inches thick, and each was, no doubt, deposited during a single period of low water. They were alternated with layers of sand and gravel.

Caving banks generally occur when the river is falling, because then the support or pressure of the river having been withdrawn from them, such as have been undermined by the rapid highwater currents topple over into the stream and thus add temporarily to the normal charge of sediment then carried in suspension. It is quite possible that the high charge of 608 grains per cubic foot, with a velocity of only 2.57 feet per second, was partly due to caving banks a few miles above.

Diagram No 2 shows that in the eight months during which the sediment observations were made at Columbus, there were six periods when the river fell from levels previously attained, and at *each period* the quantity of suspended matter diminished *at once* with the loss of current. This instantaneous evidence of the intimate relation between the velocity and the quantity carried, so clearly shown by the *weekly* mean of these quantities on the diagram, would be less apparent in curves representing each experiment. Slight errors in weight, or in current measurements and local causes, such as the caving in of the banks above the observer, might make the sympathetic action between the current and sediment appear less harmonious if the mean of a number of experiments were not taken. The weekly mean taken by the authors of the report, thus tends to bring out in bolder light the force of their own testimony against them.

In addition to errors in measurement, and caving banks, other causes, such as the differently charged waters of tributaries moving with altered velocities in the parent stream, and the difference in the time required for different kinds of sediment to deposit, may each operate to modify the results of such experiments as these we are discussing, and hence absolute synchronism in the curves of velocity and sediment cannot be expected. This agreement is however, so marked in diagram No. 2, as to bear excellent testimony to the care with which Messrs. Webster and Fillebrown conducted the experiments at Columbus.

THE BED OF THE RIVER.

The wonderful discoveries made by Humphreys and Abbot, through their unique method of investigating dynamical phenomena, are supplemented with others in geology scarcely less sur-

prising. On page 14 of their Report we find the following:

"For instance, the Mississippi had always been regarded as flowing through a channel excavated in the alluvial soil, formed by the deposition of its own sedimentary matter. So important an assumption was inadmissible; and great pains were accordingly taken to collect specimens of the bed wherever soundings were made, and by every means to ascertain the depth of the alluvial soil from Cape Girardeau to the Gulf. This investigation has resulted in proving that the bed of the Mississippi is not formed in alluvial soil, but in a stiff, tenacious clay of an older geological formation than the alluvion."

The following occurs on page 91:

"What then constitutes the real bed of the river, upon which rest the moving sand-bars, and the new willow-batture formations? From the mouth of the Ohio down, at least as far as Ft. St. Philip [forty miles above the Gulf] it seems to be composed of a single substance, a hard, blue or drab-colored clay."

The age of the bed of the river is a matter of little practical interest to the public, and I do not therefore propose to discuss it. But whether it is composed of a clay that yields slowly to the strongest currents, and resists their action "almost like marble," is a question of the utmost importance to the people of the whole country. The intelligent reader need only be told that within three years, the Congress of the United States has been advised to incur an outlay of forty-six million dollars, based on the proposition that the bed of the Mississippi will not yield to the action of its strong current, to have his curiosity aroused upon this important question.

The existence of this substratum is asserted by Humphreys and Abbot in the most confident manner, *as a fact conclusively established by the numerous soundings of the Survey with prepared leads.* We are told on page 90, in reference to these soundings, that "The details of these operations are explained in Chapter IV, and the results exhibited in Appendix C."

Turning to Chapter IV, to learn by what devices this clay had been discovered "beneath the moving sand bars and the new willow batture formations," we find them to consist of nothing more than "a sounding chain and plummet." The latter is thus described: "The sinker, varying from ten to twenty lbs. in weight according to the force of the current, was a leaden bar whose bottom was hollowed out and armed with grease, in order to bring up specimens of the bed of the river; the patent lead was also used for the latter purpose."

Now, when it is remembered that *no borings were made either on the banks or in the bed of the river to test the existence of this unyielding clay*, the reader will appreciate how astonishingly the results of these soundings have been magnified, if he will examine them in Appendix C, and compare *the facts* there recorded with the extravagant reference made to them in the report.*

On page 90, under the heading of "*Geology of the channel*," we are told that "A knowledge of the character of the bed of the Mississippi River is of the highest practical importance, as will be hereafter seen, and great efforts have been made to acquire it."

The above extract, and the statement on page 14, that "great pains were accordingly taken to collect specimens of the bed wherever soundings were made," caused me to look forward to an examination of the results of these "great efforts," as a matter of considerable labor, more especially as they had been spoken of on page 412, as "an extended series of measurements." I carefully examined the first eleven tables of soundings in Appendix C, and found that they did really constitute "an extended series of measurements;" for they comprise the only recorded lines of soundings made by Humphreys and Abbot on the Mississippi River between Cape Girardeau and Vicksburg; a distance of 650 miles! The remaining tables are the record of soundings made at Vicksburg and below that point down to Fort St. Philip, a distance of 500 miles more.

As five of the eleven lines were run

* The record of the artesian well at New Orleans is given in the report, and reference is made to it on page 465 to prove that the river deposits overlying this ancient and imaginary clay, extends only 40 feet below the level of the gulf at New Orleans, (or 55 feet below high water mark,) As a sound cedar log was struck 153 feet deep by the auger, and is reported in the record, and therefore lies 98 feet deep in this marble like clay, it is to be regretted that an explanation of how it got there, was not given the report.

across the river at Columbus, and two at Lake Providence, the other four had necessarily to be considerably *extended* to make "this investigation" into the geology of 650 miles of river a very thorough one.

About fifty soundings, more or less, were made on each one of the eleven lines, but the grease was evidently bad, or the patent lead was a failure, for, on the first line of these numerous soundings, only *one* solitary sample was obtained. The grease seems to have given out altogether on four of the lines. When the two were run across at Lake Providence this must have been the case, or it was a bad day for geological research, because no specimen whatever was obtained in either of these two lines, and thus a space nearly two hundred miles long, between Napoleon and Vicksburgh—was not sampled at all. The prepared leads appear to have worked badly on the third line also, as only two samples were obtained there. In the entire eleven lines of soundings, that were made across the river in this 650 miles, there were only *thirty-five samples* of the bottom secured!

The different kinds of material were carefully noted in a separate column under the head of "Remarks."

When we reflect that each of these precious specimens was deemed to be a key to an unwritten record running away back into the dim past, where azoic and palæozoic cycles inclose the sublime genesis of the Father of Waters, we cannot fail to note the terse expressions with which, in such simple terms as "*Gravel*, *Clay*, *Sand*, or *Mud*," these antediluvian treasures are recorded. This brevity is however, fully compensated for in Chapter II, where "the results exhibited in Appendix C are discussed."

Let us now examine the conclusive evidence given of the existence of this unyielding substratum by "the samples of the bottom which were carefully preserved for examination and comparison."

The thirty-five samples secured in this 650 miles of river, when shorn of the imposing verbiage with which they are referred to in the report, certainly constitute a very small basis on which to rest the positive statement that the bed of the Mississippi is composed of an unyielding clay, even if we suppose each one of the samples was a specimen of *clay*; but this small basis becomes supremely ridiculous when the fact is stated, that twenty-five of these samples actually consisted of pure sand, and that only *seven* of the whole thirty-five were of clay alone! And then again, each one of the seven areas thus sampled by the prepared leads was probably not larger than the palm of a man's hand!

Moses, when stopped on Mount Pisgah, might as well have tried to analyze the subsoil of the promised land by gazing at it, afar off, as for these gentlemen to tell anything about a mythical substratum of clay under the shifting deposits of the river by means of their greased leads. The present age demands *proof*, not guesswork and assertion, and it is utterly impossible that anything adhering to the bottom of a tallowed plummet from the bed of the Mississippi, can furnish any evidence whatever as to the kind of material that lies one inch below where the sample was thus secured.

It is scarcely necessary to refer to the soundings below Vicksburg, after this statement, except to say that eighty-two lines were run in that part of the river, and that 56 of these were made in 45 miles of the river near New Orleans. In 116 miles of the river between Vicksburg and Natchez, only two samples were obtained. Of the total 93 lines run, no samples were obtained in 35 of them, and of all the samples taken, only about one in four was of clay alone, while more than one-half of the whole number were of pure sand. It is needless to say that all of the samples were just such materials as the river is constantly transporting in suspension, and that they do not furnish a particle of evidence that the bed is formed of any other substance than its own deposits.

Blue clay is one of the deposits or alluvions of the river, and is found everywhere in the alluvial basin, in layers alternating with the sand, gravel and earthy deposits, which compose its bed and banks. It is found deposited in old sunken wrecks,* on sunken rafts, and on the "rack heaps," or accumulations of drift-wood which lodge against snags

* Col. Andrews states that a barge which lay submerged during only two seasons of low water at the jetties had a stratum of blue clay nearly a foot thick deposited in it, which was so tough and sticky that the men could scarcely dig it out, because it adhered to the shovels so tenaciously.

or islands. It was doubtless an old steamboat wreck, or a rack heap which caused the loss of the sounding leads, referred to in Chapter II, and which marked the chain with this blue clay thirty feet above its broken end. Yet the clay, found on the chain and the uneven depths where it was broken, led the authors of the report to suppose that the river bottom was "full of blue clay ridges and lumps many feet high."

One proof of the fact that the bed of the river *does* yield readily to the action of the current will be seen in the great number of curved lakes lying on each side of its present bed, and extending from the upper to the lower end of the alluvial district. Each one of these was once a part of the river channel. The following correct explanation of their formation is copied from page 96 of the report:

"It occasionally happens that by this constant caving, two bends approach each other, until the river cuts the narrow neck of land between them and forms a 'cut-off,' which suddenly and materially reduces its length. The increased slope of the water surface at once makes this new bed the main channel of the river. The upper and lower mouths of the 'old river' are gradually silted up with sediment, drift-wood, etc., until eventually one of the crescent-shaped lakes so common in the alluvial region is formed."

The rapidity with which the current sometimes cuts away the tough blue clay, so frequently met with in its bed and banks, may be inferred from the following account of the formation of a cut-off, given by Major Suter, U. S. Engineers, in his report:

"Davis', one of the most recent of these cut-offs, and also the largest, occurred in 1867. It cut off Palmyra Bend, eighteen miles below Vicksburg, a bend which was eighteen miles long while the distance across the neck was only 1200 feet. The exact slope of the river at the time is not known, but it was probably not far from 0.3 foot to the mile; therefore the difference of level on the two sides of the neck was about 5½ feet. When the river broke through, the whole of the fall had to be absorbed in the 1200 feet of distance, making a rate of about twenty-four feet to the mile; and it can readily be imagined that the whole immense flood volume of the Mississippi, flowing with the enormous velocity due to this great slope, produced very marked effects. The roaring of the waters could be heard for miles; and in the course of a few hours, a channel a mile wide, certainly over a hundred and probably nearly two hundred feet in depth, had been excavated."

It is impossible to reconcile the excavation in a few hours of "a channel a mile wide and certainly over a hundred and probably two hundred feet deep," with the existence of a clay that "resists the action of the strong current, almost like marble." Such a clay is undoubtedly a myth.

THE PRACTICAL IMPORTANCE OF THESE TWO QUESTIONS.

Let us now look at the immense practical importance of these two facts which are so stoutly and dogmatically denied by Humphreys and Abbot. If the quantity of suspended sediment *is* regulated by the current, and if the bed of the river *is* formed of its own sedimentary deposits, instead of this unyielding and marble like clay, then it is entirely practicable to lower its flood line or slope, and deepen its channel by simply constructing light willow or brush dams during low water on the shoals which are then dry, or nearly so, at the various wide places in the river where the bars always exist. These dams would cause the deposit of more sediment on the shoals, by checking the current, and would deepen the contracted channels that would remain by increasing the current in them. In this way (without undertaking to straighten the river, which would be supremely foolish, and impracticable), the high water channel would be brought to a comparative uniformity of width, by gradually encouraging, from year to year, the deposition of sediment over the wide expanses, and this uniformity of width would produce a uniformity of depth, which in turn would insure a uniformity of current, and this would practically stop the caving of the banks. A uniformity in the width of the high water channel would do more however than all this, for it would lower the

flood line and practically dispense with the use of levees in protecting against overflow, an area equal to the state of Indiana.

If Humphreys and Abbot's theories are sound, such an improvement of the river channel, and such abandonment of the levee system, is totally impracticable.

The following quotations show that these dangerous theories have been adopted by the United States Levee Commission, which recently recommended a system of levees below the mouth of the Ohio at an estimated cost of nearly $46,000,000. It says in its report,* page 8, [Ex. Doc. 127 H. R. 43d C. 2d Ses.] that "the assumption that the river water is always charged with sediment to its maximum supporting capacity * * * has been shown by three years of accurate daily observations, at Carrollton and Columbus, to be utterly unfounded. Indeed, it often happened that the amount of sedimentary matter per cubic foot of water was greater in low than in high stages of the river, and never was there ever any fixed relation between these quantities. In other words, Mississippi River water is undercharged with earthy matter, and therefore no reasonable reduction of its flood velocity by an outlet will produce a deposit in the bed below."

By reference to pages 135 and 137 it will be seen that this extract contains an astonishing exaggeration. Instead of *three years*, the current and sediment observations only occupied *eight months* at Columbus, and *one* year at Carrollton.

When we remember that the junior author of the report on the Mississippi river, was a prominent member of the Levee Commission, and that the senior author, as Chief of Engineers, warmly endorsed its report, it is difficult to reconcile this careless statement with the unusual scientific exactness which required four decimals to record their measurements of the current, (see page 244). In this case the reader is converted to a false theory by being gravely assured that it has been *demonstrated conclusively by three years* of daily accurate measurements at the upper and lower ends of the delta ; and in the other case, he is captivated by the wonderful precision which tells him to the ten thousandth part of a foot, the varying distances which the flowing stream has traveled at different depths below the surface, in a second of time ! As this statement is an inexcusable exaggeration, and as such exact determination of current velocities is utterly impossible by any known method of measurement, it follows that theories sustained by such testimony, cannot constitute advances in science.

*This report was reviewed by me in the *Scientific American* supplement.

On page 16, of the report of the Commission, we find the following: "It is asserted in the most confident manner that the river is flowing in a bed composed of its own deposit, with dimensions regulated in accordance with its own needs ; and hence that the increased velocity resulting from the confinement of its flood-volume between levees will rapidly excavate its bed to a correspondingly greater depth."

"This reasoning, if true, would establish conditions singularly fortunate for the Levee system; but unluckily the wish has been father to the thought. Uncompromising facts show that the premises and conclusion are both erroneous for the lower Mississippi. Very numerous soundings, with leads adapted to bring up samples of the bottom, were made by the Mississippi Delta Survey throughout the whole region between Cairo and the Gulf. They showed conclusively that the *real bed*, upon which rests the shifting sand bars and mud banks made by local causes, is always found in a stratum of hard blue clay, quite unlike the present deposits of the river. It is similar to that forming the bed of the Atchafalaya at its efflux, and, as is well known, resists the action of the strong current almost like marble."*

The results of these soundings with prepared leads are not only unduly magnified in the above statements, but the reader is also misled by the assurance that they *conclusively proved* the existence of this marble-like clay.

On page 17 of its Report this state-

*It is assumed, that because the efflux of the Atchafalaya has not deepened under the action of the current, the clay bottom there will not wear and must be something different from the ordinary river deposits. A bottom of sand would remain just as permanent when the capacity of the efflux is adjusted to the volume of discharge. The cross section of the bed, whether of clay or sand, will inevitably increase or diminish with an increase or diminution of the volume.

ment is made: "If we guard against these crevasses by raising and strengthening our levees, an elevation of the high water mark proportional to the increased volume will be sure to occur."

"To contain a quart of water a vessel must have exactly the requisite number of cubic inches; and a like principle applies with equal force to water in motion."

This is quite a novel proposition. How a like principle can apply to water in motion, I am at a loss to discover. The number of cubic inches in a quart cup is a question of space or volume only. When the water is in motion, *force* and *time* enter into the problem, and they make an elevation of the high water mark exactly proportional to the increased volume, a simple impossibility, even if the bed of the stream should not deepen. That the height would increase with the volume, as in the case of a quart cup, is simply an absurdity. But when problems in dynamics are solved without considering the elements of *space* and *time*, and the profound mysteries of remote geologic epochs, are unlocked with a greased sounding lead, we need not be surprised to learn that the most important questions in river hydraulics may be illustrated and explained with a quart cup.

If the bed of the river cannot yield, and all the crevasses in the levees are closed, the sides of the quart cup—or the levees, must be built up ten or eleven feet higher than ever before, and, therefore, the Levee Commission recommends, and the Chief of Engineers earnestly endorses, a system of levees at an estimated cost of $46,000,000, and all because the bed of the river has been conclusively proved by "an extended series of measurements," to be of an unyielding material.

A few years ago the Chief of Engineers of the U. S. Army, being equally as well convinced that the steamboat smoke pipes were, like the bed of the river, unyielding in their nature, and that they were too high to pass under the bridge, which spans the Mississippi at St. Louis, accordingly recommended that a canal with a draw-bridge, through the bridge approach, to accommodate these unyielding smoke pipes, should be dug around the end of the bridge in the ancient geologic blue clay in Illinois, at a cost of over three million dollars! The fact that the river water was proved by "a glance at the two diagrams" to be always under-charged with sediment, was an assurance that the canal would be a success and would not silt up. But Congress did not look with favor on this plan. Doubts as to the unyielding nature of the smoke pipes were openly expressed, and while the canal plans and estimates were being prepared the lucky discovery was made that the whole difficulty could be avoided by putting hinges in the pipes; and so the three million of public treasure was saved, and the commerce of the river now flows under the bridge without let or hindrance.

PRACTICABILITY OF DEEPENING THE RIVER AND LOWERING THE FLOODS.

The inclined plane formed by the *surface* of the river from the highlands down to the sea is called its slope. The intensity or *degree* of force exerted by the water in its passage depends upon the steepness of this slope. The *amount* of the force depends upon the mass or volume of the water and upon its velocity, the current being the result of the slope. The friction of the bed is the chief element which retards the current. The slope, the volume, and the friction are therefore the chief agents which determine the speed of the current. Others modify it somewhat but they need not be considered here.

Now if the reader will bear in mind that the water is charged with sediment according to its velocity, and that it flows through a bed of precisely the same kind of material it is carrying in suspension, and that if its velocity is increased it will take up a greater charge from its own bed, or if its current be slackened it will drop some of its charge in the channel, and add to its bed, he will understand the important part which the *speed* of the current performs in the problem. Through the whole alluvial basin from Cairo to the sea, the river must discharge as much sediment into the sea and over its banks, as its tributaries pour into it. If it discharged less, its channel would shoal up and its slope be steepened by the excess received from its tributaries.

If it carries more to the sea than is brought down into it from the tributaries, the excess discharged must be taken out of its own channel, and this would deepen it, and lower the slope. From this it is evident that there must be some means by which nature adjusts the speed of the current to suit the needs of the river. This is done by the relation which exists between the rate of current and the quantity of sediment carried in the water. If the velocity be too great the deepening of the bed follows. This lowers the slope and the current becomes less rapid. If the velocity on the contrary be too slow, deposition in the channel continues to take place until the river bottom is raised and the slope steepened, and a higher velocity is produced. These are the inexorable results of the relation between the current and its burden.

The river's slope, being the surface of the water, determines the height of the levees, and is therefore the vital question in the reclamation of the lands from overflow.

We see how the current alters the slope by the opposite processes of deposit and scour. We want to lower the slope to prevent overflow. When the current is too rapid, deepening is the process nature sets up in the bottom of the river, and gradually the slope is reduced and a normal current succeeds. To reduce the slope, we must temporarily increase the current. This can be done in two ways. Friction of the bed is the element which retards the velocity. Where the river is excessively wide, it will have more frictional resistance to overcome, and must there have a steeper slope. If we reduce its width at such place, the first effect will be an elevation of surface above. This will create a rapid current through the narrowed part, and it will be deepened there, and the elevation of surface above will then subside; but the current will still continue to be rapid, because the narrow and deep form of channel created will have less friction than the former wide one, and the rapid current will therefore continue to deepen the bed, until the original slope is so lowered that the current through the contracted channel is gradually reduced to the normal rate again. When this is done it will be found that the flood line or slope has been permanently lowered at that locality. This necessarily leaves the slope steeper immediately above the locality thus treated, and this induces a more rapid current, and consequent deepening of the bed, and lowering of slope still higher up. In this way the alteration of slope at one locality ultimately extends up to the head of the alluvial district. Of course this could not occur unless the most sensitive relation existed between the rate of current and the quantity of sediment suspended by it. Nor could it occur except where the bed of the river is formed of the same materials which it carries in suspension, or of materials easily eroded or moved by the current.

Another way to lower the slope is to increase the volume of water in the channel, because friction does not increase in an equal ratio with the volume. The greater is the volume, the lower is the slope, is a lesson taught by every part of the river, and by every outlet and bayou in the alluvial basin. This is because the proportion of friction to volume becomes less as the volume is increased, and, therefore, if the volume is increased, a lower slope will produce the normal rate of current, or that rate which will carry its charge of sediment to the sea without either loss or gain. It is impossible to maintain *permanently* any greater rate of current than will suffice to do this, in any sediment-bearing river in the world through its alluvial district. Bayou Atchafalaya at Red river carries a portion of the Mississippi to the sea with a fall of over six inches per mile, while the main river pursues a pathway more than three times as long, with a fall of less than two inches per mile. The greater friction in the smaller channel alone prevents a high rate of current through it. Its slope has been adjusted to maintain the rate required to discharge its waters and their earthy burden without injury to its own channel. If it were closed and its waters were compelled to flow in the main river, the first result would be an elevation of the surface and a more rapid current; a deepening of the bed would follow this, and a lowering of the slope would be the permanent result.

Lower levees would, of course, then be practicable. This teaches us that if we

wish to lower the floods and deepen the channel we must close the outlets and crevasses, and convey all of its waters through one channel to the sea. Humphreys and Abbot tell us precisely the contrary.

After an elaborate discussion on the effect of outlets and crevasses, they say : (page 420) "The conclusion is then inevitable, that *so far as the river itself is concerned they are of great utility.*"

The Levee Commission's report contains a table (page 59) from which it will be seen that from Cairo to Memphis (235 miles), there are 70 miles of crevasses and gaps in the levees, while many more exist below Memphis. It is well known that since the Rebellion in 1861, these levees have been going to destruction.

Certainly a sufficient number of outlets and crevasses have been existing and occurring here in the last 17 years to test their utility and the value of the opinion of these gentlemen on the subject.

Major Suter, U. S. Engineers, has made the most recent survey of the river, and in his report, 1875 (Ex. Doc. 19, Page 16, 43d Congress) he says: "Within the memory of living pilots the shoal water has extended down from Plum Point, one hundred miles above Memphis, to Lake Providence, fifty miles above Vicksburg, a total distance of 450 miles; and as these disturbing causes will act with more vigor every year, it is time that we should fairly face and realize the fact that, unless speedily checked, there are natural causes at work which will eventually destroy the navigability of the Mississippi and its tributary streams." Comment is unnecessary.

Since 1842, two large outlets have occurred, from artificial causes, through the narrow strip which separates the river from the gulf a few miles above the head of the passes. Through these about one-fifth of the river is now discharged. They are known as Cubitt's gap and The Jump. Surveys made in 1875 when compared with that of Talcot's made before they occurred, have revealed the fact that the depth of the river below the lowest one, has been reduced from over forty to thirty feet, and *the size of the river bed is fully one-quarter less* than it was before these crevasses occurred. I called public attention to this startling fact, to show that crevasses *do* cause shoaling in the river channel. Here is the explanation for this deposit, given by Genl. Humphreys. (See Appendix L, H. and A.'s report, 1876.) "During the low water stage of the river, there is a stratum of salt water many feet thick at the bottom in the passes and in the wide part of the river at the head of the passes, and extending above that point some distance, which has but little current either way compared to the current of fresh water on top of it; the earthy matter suspended in the river water falls upon the bottom of the river thus occupied by salt water, just exactly as it falls upon the bottom of the gulf out at sea beyond the bars, and during the low water stage a deposit is thus made on the bottom of the river."

On page 420 we are told that "there is no evidence that any filling up of the bed ever did occur in consequence of a high water outlet; and, moreover, that *it is impossible that it ever should occur*, either from the deposition of sedimentary matter held in suspension, or from the accumulation of material drifting along the bottom."

In view of the stubborn fact that this enormous shoaling *has occurred* since Cubitt's crevasse was made, it is plain that the above positive statement must be taken *cum grano salis.* Indeed it seems important for the credit of its authors that it be taken with a very large quantity of salt; for it appears that if there is a stratum of salt water under the river water, a shoal *will* occur below a crevasse. The feeblest current then, according to Gen'l Humphreys is not, *with salt under it*, capable of carrying so much sediment as the most rapid current; and the distribution of the sediment appears to be controlled by law if it has brine below it. The river water then ceases to be "always undercharged," and the relation between cause and effect is restored. The virtue of salt water is truly marvelous. "Old assumptions which experimental investigation has long since shown to be utterly unfounded in fact," become demonstrated truths, if a stratum of it be under the river water.

On page 415 of the report of Humphreys and Abbot, the following quotation is made from an article published by Major (now General) J. G. Barnard,

U. S. Engineers, in *Debow's Review* in 1850.

"'I find this principal laid down in the work of Frisi, 'On Rivers and Torrents,' which was placed in my hands by W. S. Campbell. He quotes and confirms the rules established by another engineer, Guglielmini, which are that 'the greater the quantity of water a river carries, *the less will be its fall*,' and 'the greater the force of the stream, the less will be the slope of its bed.' And, again, 'the slope of the bottom in rivers will diminish in the same proportion in which the body of water is increased,' and *vice versa*. These rules have their explanation in the facts that the beds of rivers, of the character above mentioned [like the lower Mississippi], are capable of resisting, unchanged, only a certain velocity of current; and, on the other hand, that the sedimentary matter contained in the river water, requires a certain degree of velocity to keep it in suspension. From the counteracting tendencies of the above two causes, a mean becomes established, at which the current ceases to deposit its sediment, and the bottom ceases to be abraded; in other words, the bottom becomes permanent. But if, from any cause, such as throwing off a portion of the water through a waste-weir, the velocity of the current is diminished, it is no longer able to maintain its sediment in suspension, but will continue to deposit in its bed, until, through the elevation of the bed, its velocity again becomes what it was before it was disturbed, sufficient to maintain its sediment in permanent suspension."'

As this proposition is fully sustained by the Columbus and Carrollton experiments, and is conclusively proved by the phenomena presented all through the alluvial basin, the summary manner in which it is disposed of by Humphreys and Abbot is amusing. They say:

"It will be noticed that two important assumptions are necessary to support this reasoning: First, *that the bottom of the Mississippi is composed of its own alluvion, which can be readily acted upon by the current;* and, second, that its water is *always charged with sediment to the maximum capacity allowed by its velocity.*

"Throughout the whole distance from Cairo to Fort St. Philip the true bed consists of a tenacious clay which is unlike the alluvial soil, wears slowly under the strongest currents, and is, proved, by conclusive evidence, to belong to a geological formation antecedent to the present. This disposes of the first assumption.

"We come, then, to the second assumption, viz: that the water is at all times charged with sediment to the maximum capacity allowed by its velocity. * * * A glance at the two diagrams (plates XII and XIII) is sufficient to demonstrate the falsity of the assumption, that Mississippi water is always charged with sediment to the maximum capacity allowed by its velocity. * * * The second assumption is, then, as untenable as the first."

THE RELATION BETWEEN THE CURRENT AND SEDIMENT IS EXCEEDINGLY SENSITIVE.

Owing to the great width of the river at the head of the passes, the depth at the entrance into each pass is much shoaler than it is in the pass. South pass is about 700 feet wide, and over thirty feet deep, but the water entering it was about 2,800 feet wide half a mile above its entrance, and at this place the channel was but fourteen feet deep. To concentrate this 2,800 feet into a narrow and deep channel, I erected, with other more substantial works, a dam or willow screen 1,900 feet long across the current on the eastern side of this shoal. The dam consisted of a single thickness of willow mattress held in a vertical position by piles, the willow work being only two feet thick, and the depth of water being from twelve to sixteen feet. Of course the current passed through the willows with but little hindrance. It was not intended to be an impervious dam, and the whole structure was only strong enough to resist stormy weather. It was built with the practical knowledge that a *very slight* retardation of the current *will* cause a deposit. Two floods caused so great a deposit both above and below it that a small row boat can not now get to the dam at low tide. In another season or two, vegetation will probably cover this deposit and extend many hundred feet above the dam,

and an area of more than one hundred acres of dry land will occupy the space between the dam and the main land below. The channel through the shoal is now twenty-two feet deep at low tide.

In the Department of Public Works at St. Petersburg I was shown a device similar to a Venetian blind, formed with small ropes and wooden slats, that was said to have been successfully used on the Volga for the same purpose as the willow dam I have described.

These results can be explained on no other theory than that the amount of sediment carried is strictly regulated by the velocity of the current. The burden can only be carried by the expenditure of force. Nature adjusts the quantity to the force, and if we absorb any portion of the force even by the resistance of a porous willow dam, less force will remain to carry the burden and some of it must then fall to the bottom.

It is simply impossible that the work done, or load carried, can be greater than the force expended, or that the effect can be greater than the cause; and hence we cannot compel the force that is required by nature to transport the sediment, to do any other work, even so much as the turning of a mill wheel, or absorb any part of it by the friction of a dam made with open willow twigs, or even with one made with a fish net, without lessening, by so much, the force which is being expended in transporting the sediment. If we do, a deposition of a portion of the load must result, and it must continue to fall until, by the raising of the bed, a new regimen is established.

MOMENTUM AND VIS VIVA.

By S. BARNETT, Jr.

Written for VAN NOSTRAND'S MAGAZINE.

In the June number of VAN NOSTRAND'S ENGINEERING MAGAZINE, we find the following from Prof. Skinner: " . . . . , I was arguing that writers who prefer to derive the unit of mass by definition from the unit of force ought to first make their arbitrary unit of force invariable, so that there should be a definite ratio between the units of mass and of force in the two systems; and so that students could pass by simple multiplication or division from one to the other."

Now, not to dwell upon the fact that some unit of mass or other must be determined before we can fix a unit of force, we may inquire what would be the nature of this ratio of the unit of mass to that of force. If the quotient of mass divided by force is an arithmetical number, that is of zero dimensions, mass and force are the same thing. Force would be nothing but mass, or mass nothing but force. But if mass is not force, the ratio of the two must be of dimensions other than zero in, at least, one denomination; say length or time, and this ratio will depend upon such other unit or units. It is necessary to show how the ratio so depends, and this Professor Tait showed in his Glasgow lecture in comparing force and momentum, or, at least, partly showed, but which Prof. Skinner said seemed to him "an arrangement of no validity."

Further, Prof. Skinner says: "But if *force* is nothing but a *rate of doing work*, then work is nothing but the action of a *rate of doing work*, and we may just as well say that *force* is *force* and *work* is *work*, and confess that we know nothing of either of them." We should hardly accept this, however, as the conclusion of the whole matter. There is not the least difficulty in the conception and exact expression of the product of the space passed over into the rate of change of momentum. In mathematical symbols

$$\text{work} = \int_b^a \frac{d(mv)}{dt} ds.$$

Also the rate of doing work per unit of length is force or the rate of change of momentum.

$$i.e., \quad \frac{dW}{ds} = \frac{d}{ds}\int_b^a \frac{d(mv)}{dt} ds = \frac{d(mv)}{dt}$$

The non-mathematical reader should

know that work is the sum of the elementary spaces passed through, each multiplied by the rate of change of momentum per unit of time at the point.

As regards the remarks of Thomson and Tait that, "It is therefore very much simpler and better to take the imperial pound" for the unit of mass, &c., we simply add—"Unquestionably so, for all practical purposes." And indeed the absolute unit of force only needs an absolute unit of mass no matter how derived; the assumption is only necessary so far as the unit of force is concerned. The practical difficulty of replacing units of mass by their relations to those of time and length has nothing to do with the theoretical perfection of the method.

REMARKABLE CHANGES IN THE EARTH'S MAGNETISM.*

From "Nature."

One of the most important, scientifically, of the special lectures at the Geographical Society, was that by Capt. Evans, in March last, on the subject of terrestrial magnetism. The concluding portion, especially, is of high scientific importance. Capt. Evans gave a historical sketch of the subject of terrestrial magnetism from the time of the discovery of the dip of the magnetic needle. After speaking further on various departments of his subject, Capt. Evans went on to say:

We have now passed in review the successive stages of development of our branch of knowledge, from the pregnant epoch when its principles were enunciated by Gilbert, till the period when the well-directed munificence of his own and other Governments dotted the earth's surface with observatories, and despatched land and sea expeditions, specially equipped, for the determination of the magnetic elements. We have seen how a few earnest and gifted men have, by long and patient analysis, laid the foundations for future generations to build upon as regards theory, and unravelled the apparently inextricable web surrounding the needle's daily and yearly movements; tracing these movements to their primary source, the sun: and how by the perseverance of states and of individuals, we are now in possession of accurate knowledge as to the distribution of magnetism over the surface of our globe, as represented by the variation and dip of the needle, and by the measure of the force connected with those component elements. But the task, from a scientific point of view, is far from completed while we remain in ignorance of the causes of greater changes in the earth's magnetism going on from year to year, and so on, possibly through æons of time. From a practical point of view, so far as the interests of men are concerned, the collection of records will be a never ending task, for every generation must observe and chart the magnetic elements of its time.

The subject of secular change is thus one of such great interest that the remaining portion of my lecture must be chiefly devoted to it. The active mind of Halley was drawn, as one of the first, to the probable nature of the causes; collecting such observations of the variation of the compass as had then been made, and projecting them on polar maps, he found that the convergence of the several directions of the needle led to two points in each hemisphere. On this he enunciated the proposition "that the whole globe of the earth is one great magnet, having four magnetical poles or points of attraction; near each pole of the equator two; and that in those parts of the world which lie near adjacent to any of these magnetic poles the needle is governed thereby, the nearest pole always being predominant over the more remote." Halley saw, as he confessed with despair, the difficulties attending the proposition, "as never having heard of a magnet having four poles," but there were the facts manifested by the earth, and he was too sagacious and sound a

* From Lecture at the Royal Geographical Society, March 11, by Captain F. J. Evans, C.B., F.R.S, Hydrographer to the Admiralty.

philosopher to pass them by. He accordingly propounded a theory which, however fantastic it may now appear, and perhaps did at the time he wrote, has nevertheless within it the fire of genius, and may probably be found yet to contain some sparks of truth. To account for the four poles, and at the same time for the secular change of the variation, he conceived that the earth itself might be a shell, containing within a solid globe, or terella, which rotated independently of the external shell; each globe having its own magnetic axis passing through the common center; but the two axes inclined to each other and to that of the earth's diurnal rotation. It is not difficult to follow the movements of the consequent four imaginary poles in solution of the problem.

Hansteen working at the same problem a century after Halley [1811–19], and much on the same lines, came nearly to the same conclusion with regard to the four poles of attraction; and he rendered justice to Halley by recognizing him as the first who had discovered the true magnetic attraction of the globe. Hansteen, with the material at his command, went however a step further, and computed both the geographical positions and the probable period of the revolution of this dual system of poles or points of attraction round the terrestrial pole. From these computations he found that the North American point or pole required 1,740 years to complete its grand circle round the terrestrial pole, the Siberian 860 years; the pole in the Antarctic regions south of Australia, 4,609 years; and a secondary pole near Cape Horn, 1,304 years. The influence of these laborious investigations on the minds of subsequent inquirers may easily be imagined.

The matured views of Sir Edward Sabine on the secular changes—enunciated in the clearest manner in 1864–72 –are deserving of the highest consideration. An ardent admirer of the genius and no less of the sagacity of Halley, he in part follows Halley's views, and considers that two magnetic systems are directly recognisable in the phenomena of the magnetism of the globe; the one having a terrestrial, the other a cosmical origin. The magnetism *proper* of the globe, with its point of greatest attraction (*i.e.* in the northern hemisphere) in the north of the American continent is the stronger; the weaker system, or that which results from the magnetism induced in the earth by *cosmical action*, with its point of greatest attraction is, at present, in the north of the Asiatic continent. Sir Edward Sabine also expresses his belief that "it is the latter of these two systems which by its progressive translation, gives rise to the phenomena of secular change, and to those magnetical cycles which owe their origin to the operation of the secular change."

Reviewing these several hypotheses by the light of observations made in recent years, it is difficult, and indeed in some directions, impossible to recognise their accordance with changes now going on; there can be no doubt, notwithstanding, that Halley and Hansteen analyzed their facts with skill, and that their deductions were borne out by those facts. In explanation of this anomaly it is necessary to glance retrospectively on the changes in progress at the times in which these philosophers gave utterance to their views [1700–1819]. During this long interval, and, so far as relates to parts of the northern hemisphere, for a century before, there was in the higher latitudes a general movement of the north end of the needle in the following directions:

Over all that area (embracing the Atlantic and Indian Oceans) from Hudson's Bay to about the meridian of the North Cape of Europe, and from Cape Horn to about the western part of Australia, the north end of the needle was successively drawn to the west at a maximum rate of 8′ or 10′ a year. From the meridian of the North Cape of Europe to that of 130° east, it was successively drawn to the east, while from thence to Hudson's Bay it was nearly stationary, or perhaps oscillated a little; in the southern hemisphere, from about the western part of Australia to Cape Horn, the movement was throughout to the east at the maximum rate of 7′ a year. There was thus a general uniformity of movement; in that hemisphere (dividing the globe into *eastern* and *western* hemispheres) which includes the Atlantic and Indian Oceans, the needle was constantly drawn more and more to the west; in the hemisphere

embracing the Pacific Ocean, more and more to the east.

So far then to the early part of the present century we can trace a harmonious movement of the needle over the whole globe, justifying the conclusions of our old philosophers; but in the year 1818 at London, and generally contemporaneous with that epoch throughout Europe and North Africa, the westerly progress of the north end of the needle ceased, and an easterly movement commenced; this continues to the present time, and with a yearly increasing rate. But in the South Atlantic during this period the westerly movement has never ceased; it is still going on, and in some parts with rapidity. Here, then, is a marked dislocation of the harmonious regularity embodied in Halley's and Hansteen's calculations and conceptions.

The matured views of Sir Edward Sabine, to which I have drawn attention, seem to anticipate the difficulties attendant on this new and complex movement; for, if I apprehend his meaning correctly, they imply that the poles of attraction which have a terrestrial source, *i.e.* the *magnetic poles*, are not subject to translation.*

The hypothesis, if further followed, is nevertheless beset with difficulties; for we can scarcely conceive changes due to *cosmical* action to be otherwise than general in character, and to affect the whole globe. Thus, if the progressive translation of the induced or weaker system in Northern Asia—and presumably of that in the southern hemisphere—were the direct causes of the secular charges, we should anticipate uniformity in the general movements of the needle as manifested by its variation and dip over the earth's surface. But this is contrary to modern experience; for in some regions great activity of movement, both in the direction of pointing and in the inclination of the needle, is going on; in others there is comparative repose in both elements; while in another region the needle remains nearly constant in its direction, while its inclination sensibly varies from year to year. For example:

A region of remarkable activity presents itself in the South Atlantic Ocean; a great part of the seaboard of South America extending to Cape Horn, and including St. Paul's Rocks, Ascension, St. Helena, and the Falkland Islands, with their adjacent seas, are embraced therein. In some parts of this area the westerly movement of the needle exceeds 7′ or 8′ a year, and has so progressed for nearly three centuries. On the American coast the dip of the south end of the needle *decreases* from 7.5′ to 4′ yearly, while from the Cape of Good Hope to Ascension it *increases* from 5′ to 10′ yearly. We have here, within narrow limits, a noteworthy dislocation of the observed phenomena.

Another region of activity, so far as is denoted by the changes of variation, extends over Europe, Western Asia, and North Africa. Here the needle, in opposition to the protracted westerly movement going on in the South Atlantic, commenced moving to the eastward in the early part of this century; it has a progressive rate which in some parts now amounts to 10′ a year. The dip diminishes in this region seldom more than 3′ a year.

A region of activity, so far as the dip is concerned, but with little change in the variation, is to be found on the west coast of South America; at Valparaiso, as at the Falkland Islands, the south dip decreases at the rate of 7′ yearly, but in sailing northward and reaching the 10th degree of south latitude, this active movement appears to cease.

But little activity in either element now exists over the habitable part of the North American continent or in the West Indies. Throughout China there is little change in the variation, but an *increasing* dip of 3′ or 4′, and thus a reverse movement to that going on in Europe.

Over a great part of the Western Pacific Ocean, as also in Australia and New Zealand, there is so little change in the two elements that this may be termed a region of comparative repose.

These are a few facts relating to secular changes going on in two magnetic elements within our own time; and what are the inferences to be drawn therefrom? They appear to me to lead to the conclusion that movements, cer-

* So far as modern observations bear on the position of the magnetic poles, they indicate permanency rather than change of place.

tainly beyond our present conception, are going on in the interior of the earth; and that so far as the evidence presents itself, secular changes are due to these movements and not to external causes; we are thus led back to Halley's conception of an internal nucleus or inner globe, itself a magnet, rotating within the outer magnetised shell of the earth.

We need not here pause to discuss the probability of this fanciful conception of the old philosopher, but proceed to examine how far the behavior of another element, the intensity of the earth's magnetism, confirms the view that movements are going on in the interior of our globe. In common I believe with all those who have pursued the study of this element, from the time when Sabine's original memoir to the British Association (1837) threw so much light on this special division of the subject, I had conceived that stability, within very limited conditions, was a distinctive condition of the earth's force; and that it was alone by watchful attention to the instruments of precision devised for its determination that changes in short intervals of time, such as a generation, could be detected.* If we turn to the results obtained in this country through nearly half a century, it is possible that an *increase* of two or three hundredths of the total force may be found. In Italy at the present time the annual *decrease* has been given by that active observer, the Rev. Father Perry, as .004; so also on the North American continent, where, as we are told by the zealous magnetician, Schott, there is evidence of the force slightly increasing at Washington, of being stationary at Toronto, in Canada, and slightly decreasing at Key West, in the Gulf of Mexico. So far stability, within very small limits, obtains over a very large part of the northern hemisphere. If, however, we turn to the continent of South America and its adjacent seas (parts of which are regions of marked activity as denoted by changes in the variation and dip of the needle), we shall find a diminution of the intensity of the earth's force now going on in a remarkable degree; an examination of the recent observations made by the *Challenger's* officers at Valparaiso and Monte Video, compared with those made by preceding observers, show that within half a century the whole force had respectively diminished one-sixth and one-seventh—at the Falkland Islands one-ninth. Farther north we find at Bahia and Ascension Island, in the same period of time, an equally marked diminution of one-ninth of the force. This area of *diminishing* force has wide limits; it would appear to reach the equator and to approach Tahiti on the west and St. Helena on the east; at the Cape of Good Hope there is evidence of the force *increasing.*

Such are the facts, and how are we to interpret them? Whichever way we look at the subject of the earth's magnetism and its secular changes, we find marvelous complexity and mystery; lapse of time and increase of knowledge appear to have thrown us farther and farther back in the solution. The terella of Halley, the revolving poles of Hansteen, and the more recent hypotheses of the ablest men of the day, all fail to solve the mystery. We must not, however, be discouraged at these repulses in the great conflict for the advancement of human knowledge. The present century has been productive of keen explorers in the field of terrestrial magnetism; others emulous of fame are pressing rapidly from the rear, and knowing as we do that knowledge shall be increased, we may confidently anticipate the day when this, one of Nature's most formidable secrets, shall be revealed.

* The investigations of that able magnetician, Mr. Broun, led him to consider that the earth's magnetic force increases and diminishes from day to day by nearly the same amount over the whole globe. These increases and diminutions have been traced to the action of the sun in such a way that the greatest of them recur frequently at intervals of twenty-six days, or multiples of twenty-six days—a period attributable to the sun's rotation.

THE telephone has been adopted on the mountain section of the Central Pacific Railway. The points supplied are Truckee, Blue Cañon, Summit, Cascade, Strong's Cañon, Yuba Pass, Tamarack, and Camp 3. The main office is at Blue Cañon, and each track-walker is compelled to report himself both in passing east and west. The telephones are to be placed at distances of a very few miles apart, to enable the "track-walkers," or platelayers, to make any necessary requests or other communications, as to state of road.

THE THEORY OF INTERNAL STRESS IN GRAPHICAL STATICS.

By HENRY T. EDDY, C. E., Ph. D., University of Cincinnati.

Written for VAN NOSTRAND'S MAGAZINE.

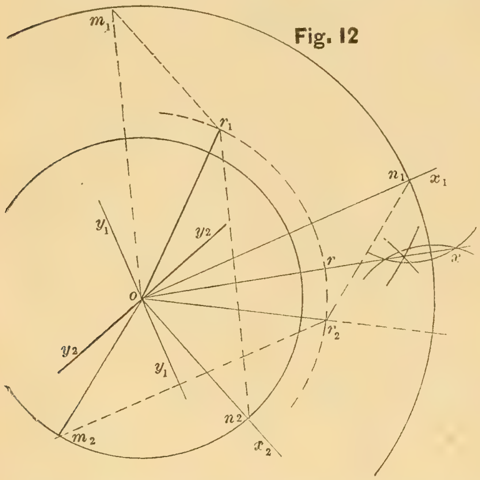
III.

COMBINATION AND SEPARATION OF STATES OF STRESS.

PROBLEM 19.—When two given states of right shearing stress act at the same point, and their principal stresses have a given inclination to each other, to combine these states of stress and find the resultant state.

In Fig. 12 let ox_1, ox_2 denote the directions of the two given principal + stresses, and let $a_1=on_1$, $a_2=on_2$ represent the position and magnitude of these principal stresses. Since the given stresses are right shearing stresses $a_1=-b_1$, $a_2=-b_2$ and the respective planes of shear bisect the angles between the principal stresses. Now it has been previously shown that the intensity of the stress caused by the principal stresses $a_1=-b_1$ is the same on every plane traversing o: the same is true of the principal stresses $a_2=-b_2$: hence, when combined, they together produce a stress of the same intensity on every plane traversing o. This resultant state of stress evidently does not cause a normal stress on every plane, hence the resultant state must be a right shearing stress.

Fig. 12



Let us find its intensity as follows: The principal stresses $a_1=-b_1$ cause a stress on_1 on the plane y_1y_1, and the principal stresses $a_2=-b_2$ cause a stress om_2 on the same plane in such a direction that $x_2om_2=x_1ox_2$, as has been before shown. Complete the parallelogram $n_1om_2r_2$; then or_2 represents the intensity and direction of the stress on y_1y_1. But the principal stresses bisect the angles between the normal and the resultant intensity, therefore, ox, which bisects x_1or_2, is the direction of a principal stress of the resultant state, and $or=or_2=a$ is the intensity of the resultant stress on any plane through o.

The same result is obtained by finding the stress the plane y_2y_2, in which case we have $on_2=a_2$ acting normal to the plane, and $om_1=a_1$ in such a direction that $x_1om_1=x_2ox_1$. The sides and angles of $n_2om_1r_1$ and $n_1om_2r_2$ are evidently equal, hence the resultants are the same, $or_1=or_2=a$, and ox bisects x_2or_1.

The algebraic solution of the problem is expressed by the equation,

$$a^2=a_1^{\ 2}+a_2^{\ 2}+2a_1a_2\cos 2\,x_1x_2,$$

from which a may be found, and, finally, the position of or is found from the proportion,

$$\sin 2xx_1 : a_2 :: \sin 2xx_2 : a_1 :: \sin 2x_1x_2 : a.$$

PROBLEM 20.—When any two states of stress, defined by their principal stresses, act at the same point, and their principal stresses have a given inclination to each other, to combine these states and find the resultant state.

Let a_1, b_1, and a_2, b_2 be the given principal stresses, of which a_1 and a_2 have the same sign and are inclined at a known angle x_1x_2, but in so taking a_1 and a_2 they may not both be numerically greater than b_1 and b_2 respectively.

Separate the pair of principal stresses $a_1\,b_1$ into the fluid stress $+\frac{1}{2}(a_1+b_1)$, and the right shearing stress $\pm\frac{1}{2}(a_1-b_1)$ as

has been previously done; and in a similar manner the principal stresses $a_2\ b_2$ into $+\frac{1}{2}(a_2+b_2)$ and $\pm\frac{1}{2}(a_2-b_2)$. Then the combined fluid stresses produce a fluid stress of $+\frac{1}{2}(a_1+b_1+a_2+b_2)$ on every plane through *o;* and the combined right shearing stresses cause a stress whose intensity and position can be found by Problem 19.

The total stress is obtained by combining the total fluid stress with the resultant right shearing stress.

Of course, any greater number of states of stress than two, can be combined by this problem by combining the resultant of two states with a third state and so on.

The algebraic expression of the combination of any two states of stress is as follows:

$$(a+b)=(a_1+b_1+a_2+b_2),$$

$$(a-b)^2=(a_1-b_1)^2+(a_2-b_2)^2 +2(a_1-b_1)\ (a_2-b_2)\cos 2x_1x_2,$$

$$\therefore\ a=\tfrac{1}{2}(a_1+b_1+a_2+b_2+[(a_1-b_1)^2 +(a_2-b_2)^2+2(a_1-b_1)(a_2-b_2)\cos 2x_1x_2]^{1/2}),$$

$$b=\tfrac{1}{2}(a_1+b_1+a_2+b_2-[(a_1-b_1)^2+(a_2-b_2)^2 +2(a_1-b_1)(a_2-b_2)\cos 2x_1x_2]^{1/2}),$$

in which a and b are the resultant principal stresses. Also, $\sin 2xx_1 : a_2-b_2$

$$: : \sin 2xx_2 : a_1-b_1\ : :\ \sin 2x_1x_2 : a-b.$$

PROBLEM 21.—In a state of stress defined by the stresses upon two planes at right angles to each other, to find the principal stresses.

Let the given stresses be resolved into tangential and normal components; it has been shown that the tangential components upon these planes are of equal intensity and unlike sign. Let the intensity of the tangential component be a_t, and that of the normal components a_n and b_n respectively. The tangential components together constitute a state of right shearing stress of which the given planes are the planes of shear, and the principal stresses bisect the angles between the given planes.

Separate the remaining state of stress into the fluid stress $+\frac{1}{2}(a_n+b_n)$ and the right shearing stress $\pm\frac{1}{2}(a_n-b_n)$, and combine this last right shearing stress with that due to the tangential components. The final result is found, just as in Problem 20, by combining the fluid stress $\frac{1}{2}(a_n+b_n)$ with the resulting right shearing stress.

This problem can also be solved in a manner similar to that employed in Problem 6.

The result is expressed by the equations,

$$a+b=a_n+b_n,$$

$$(a-b)^2=(a_n-b_n)^2+4a_t{}^2$$

for the angle which has been heretofore denoted by x_1x_2 is in this case 45° ∴ $\cos 2x_1x_2=0$

$$\therefore\ a=\tfrac{1}{2}(a_n+b_n+[(a_n-b_n)^2+4a_t^2]^{1/2})$$

$$b=\tfrac{1}{2}(a_n+b_n-[(a_n-b_n)^2+4a_t^2]^{1/2})$$

$$\sin 2xx_1 : 2a_t : : \sin 2xx_2 : a_n-b_n : : 1 : a-b,$$

but $2xx_1=90°-2xx_2$,

$$\therefore\ \tan 2xx_1=2a_t \div (a_n-b_n).$$

PROBLEM 22.—In a state of stress defined by two simple stresses which act at the same point and have a given inclination to each other, to combine them and find the resultant state.

It has been previously mentioned that any simple stress as a_1 can be separated into the fluid stress $+\frac{1}{2}a_1$ and the right shearing stress $\pm\frac{1}{2}a_1$, as it is simply a case in which $b_1=0$. Hence the simple stresses a_1, a_2 can be combined as a special case of Problem 20, in which b_1 and b_2 vanish. The results are expressed algebraically as follows:

$$a+b=a_1+a_2,$$

$$(a-b)^2=a_1{}^2+a_2{}^2+2a_1a_2\cos 2x_1x_2,$$

$$\therefore\ ab=\tfrac{1}{2}a_1a_2(1-\cos 2x_1x_2)$$

$$\therefore\ ab=a_1a_2\sin^2 x_1x_2.$$

Since a simple compression or tension produces a simple stress in material, this problem is one of frequent occurrence, for it treats the superposition of two, and hence of any number of simple stresses lying in the same plane.

This problem is of such importance that we think it useful to call attention to another solution of it, suggested by the algebraic expressions just found.

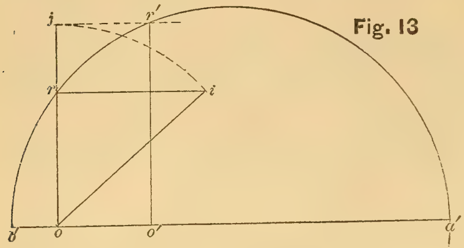
In Fig. 13 let

$$o'a'=a_1,\ o'b'=a_2\ \therefore\ o'r'=\sqrt{a_1a_2}=oi.$$

Now, if $oir=x_1x_2$, then $or=o'r'\sin x_1x_2$

$$\therefore\ \overline{or}^2=oa'.ob'=o'a'.o'b'\sin^2 x_1x_2$$

$$\therefore\ oa'=a \text{ and } ob'=b.$$



This solution is treated more fully in Problem 23.

PROBLEM 23.—When a state of stress is defined by its principal stresses, it is required to separate it into two simple stresses having a given inclination to each other.

It was shown in Problem 22 that
$$a+b=a_1+a_2, \text{ and } ab=a_1a_2 \sin x_1x_2.$$

Let us apply these equations in Fig. 13 to effect the required construction. Make $oa'=a$, $ob'=b$; then $a'b'=a_1+a_2$. At o erect a perpendicular to $a'b'$ cutting the circle of which $a'b'$ is the diameter at r; then $\overline{or}^2=ab$, the product of the principal stresses. Also make $a'oi=x_1x_2$ the given inclination of the simple stresses, and let $ri \parallel a'b'$ intersect oi at i; then $or=oi \sin x_1x_2 \therefore \overline{oi}^2=a_1a_2$.

Make $oj=oi$ and draw $jr' \parallel a'b'$, then
$$o'r'=oi, \text{ and } o'a'.o'b'=\overline{o'r'}^2,$$
$$\because o'a'=a_1 \text{ and } o'b'=a_2,$$
the required simple stresses. This construction applies equally whether the given principal stresses are of like or unlike sign, and also equally whether the two simple stresses are required to have like or unlike signs.

PROBLEM 24.—When a state of stress is defined by its principal stresses, to find the inclination of two given simple stresses into which it can be separated.

In Fig. 13 let $oa'=a$, $ob'=b$ be the intensities of the principal stresses, and $o'a'=a_1$, $o'b'=a_2$ be the intensities of the given simple stresses. It has been already shown that $a+b=a_1+a_2$. Draw the two perpendiculars or and $o'r'$; through r draw $ri \parallel a'b'$; make $oi=oj=o'r'$; then is $oir=ioa'$ the required inclination, for it is such that
$$ab=a_1a_2 \sin^2 x_1x_2$$

PROBLEM 25.—To separate a state of right shearing stress of given intensity into two component states of right shearing stress whose intensities are given, and to find the mutual inclination of the principal stresses of the component states.

In Fig. 12, about the center o, describe circles with radii $on_1=a_1$, $on_2=a_2$, the given component intensities; and also about o at a distance $or_1=a$, the given intensity. Also describe circles with radii $r_1m_1=on_2$, $r_1n_2=on_1$ cutting the first mentioned circles at m_1 and n_2: then is $\frac{1}{2}n_2om_1=x_1x_2$ the required mutual inclination of the principal stresses of the component states. This is evident from considerations previously adduced in connection with this figure. The relative position of the principal stresses and principal component stresses is also readily found from the figure.

PROBLEM 26.—In a state of right shearing stress of given intensity to separate it into two component states of right shearing stress, when the intensity of one of these components is given and also the mutual inclination of the principal stresses of the component states.

In Fig. 12, about the center o describe a circle rr with radius $or=a$, the intensity of the given right shearing stress, and at n_1, at a distance $on_1=a_1$ from o which is the intensity of the given component, make $x_1n_1r_2=2x_1x_2$, twice the given mutual inclination; then is n_1r_2 the distance from n_1 to the circle rr the intensity of the required component stress. The figure can be completed as was done previously.

It is evident, when the component a_1 exceed a, that there is a certain maximum value of the double inclination, which can be obtained by drawing n_1r_2 tangent to the circle rr, and the given inclination is subject to this restriction.

Other problems concerning the combination and separation of states of stress can be readily solved by methods like those already employed, for such problems can be made to depend on the combination and separation of the fluid stresses and right shearing stresses into which every state of stress can be separated.

PROPERTIES OF SOLID STRESS.

We shall call that state of stress at a point *a solid stress* which causes a stress on every plane traversing the point. In the foregoing discussion of plane stress no mention was made of a stress on the plane of the paper, to which the plane stress was assumed to be parallel. It is, evidently, possible to combine a simple stress perpendicular to the plane of the paper with any of the states of stress heretofore treated without changing the stress on any plane perpendicular to the paper.

Hence in treating plane stress we have already treated those cases of solid stress which are produced by a plane stress combined with any stress perpendicular to its plane, acting on planes also perpendicular to the plane of the paper.

We now wish to treat solid stress in a somewhat more general manner, but as most practical cases are included in plane stress, and the difficulties in the treatment of solid stress are much greater than those of plane stress, we shall make a much less extensive investigation of its properties.

Conjugate Stresses.—Let xx, yy, zz be any three lines through o; now, if any state of stress whatever exists at o, and xx be the direction of the stress on the plane yoz, and yy that on zox, then is zz the direction of the stress on xoy: *i.e.*, each of these three stresses lies in the intersection of the planes of action of the other two.

Reasoning like that employed in connection with Fig. 1, shows that no other direction than that stated could cause internal equilibrium; but a state of stress is a state of equilibrium, hence follows the truth of the above statement.

Tangential Components.—Let xx, yy, zz be rectangular axes through o; then, whatever may be the state of stress at o, the tangential components along xx and yy are equal, as also are those along yy and zz, as well as those along zz and xx.

The truth of this statement flows at once from the proof given in connection with Fig. 3.

It should be noticed that the total shear on any plane xoy, for example, is the resultant of the two tangential components which are along xx and yy respectively.

State of Stress.—Any state of solid stress at o is completely defined, so that the intensity and direction of the stress on any plane traversing o can be completely determined, when the stresses on any three planes traversing o are given in magnitude and direction.

This truth appears by reasoning similar to that employed with Fig. 4, for the three given planes with the fourth enclose a tetrahedron, and the total distributed force acting against the fourth plane is in equilibrium with the resultant of the forces acting on the first three.

Principal Stresses.—In any state of solid stress there is one set of three conjugate stresses at right angles to each other, *i.e.* there are three planes at right angles on which the stresses are normal only.

Since the direction of the stress on any plane traversing a given point o can only change gradually, as the plane through o changes in direction, it is evident from the directions of the stresses on conjugate planes that there must be at least one plane through o on which the stress is normal to the plane. Take that plane as the plane of the paper; then, as proved in plane stresses, there are two more principal stresses lying in the plane of the paper, for the stress normal to the plane of the paper has no component on any plane also perpendicular to the paper.

Fluid Stress.—Let the stresses on three rectangular planes through o be normal stresses of equal intensity and like sign; then the stress on any plane through o is also normal of the same intensity and same sign.

This is seen to be true when we combine with the stresses already acting in Fig. 5, another stress of the same intensity normal to the plane of the paper.

Right Shearing Stress.—Let the stresses on three rectangular planes through o be normal stresses of equal

intensity, but one of them, say the one along xx, of sign unlike that of the other two; then the stress on any plane through o, whose normal is $x'x'$, is of the same intensity and lies in the plane xox' in such a direction rr that xx and the plane yz bisect the angles in the plane xox' between rr and its plane of action, and rox' respectively.

The stress parallel to yz is a plane fluid stress, and causes therefore a normal stress on the plane xox'. Hence the resultant stress is in the direction stated, as was proved in Fig. 6.

Component States of Stress.—Any state of solid stress, defined by its principal stresses abc along the rectanglar axes of xyz respectively, is equivalent to the combination of three fluid stresses, as follows:

$\frac{1}{2}(a+b)$ along x and y, $-\frac{1}{2}(a+b)$ along z;
$\frac{1}{2}(c+a)$ along z and x, $-\frac{1}{2}(c+a)$ along y;
$\frac{1}{2}(b+c)$ along y and z, $-\frac{1}{2}(b+c)$ along y;

For these together give rise to the following combination:

$\frac{1}{2}(a+b)+\frac{1}{2}(c+a)-\frac{1}{2}(b+c)=a$, along x;
$\frac{1}{2}(a+b)-\frac{1}{2}(c+a)+\frac{1}{2}(b+c)=b$, along y;
$\frac{1}{2}(a+b)+\frac{1}{2}(c+a)+\frac{1}{2}(b+c)=c$, along x.

In case $b=0$ and $c=0$ this is a simple stress along x.

Component Stresses.—Any state of solid stress defined by its principal stresses can also be separated into a fluid stress and three right shearing stresses, as follows:

$\frac{1}{4}(a+b+c)$ along x, y, z;

$\frac{1}{4}(a-b-c)$ along x, and $-\frac{1}{4}(a-b-c)$ along y and z;

$\frac{1}{4}(b-c-a)$ along y, and $-\frac{1}{4}(b-c-a)$ along z and x;

$\frac{1}{4}(c-a-b)$ along z, and $-\frac{1}{4}(c-a-b)$ along x and y;

It will be seen that the total stresses along $x\ y\ z$ are $a\ b\ c$ respectively. This system of component stresses is remarkable because it is strictly analagous in its geometric relationships to the trammel method used in plain stress. We shall simply state this relationship without proof, as we shall not use its properties in our construction.

If the distances $pa_1=a$, $pb_1=b$, $pc_1=c$ be laid off along a straight line from the point p, and then this straight be moved so that the points $a_1\ b_1\ c_1$ move respectively in the planes yz, zx, xy; then p will describe an ellipsoid, as is well known, whose principal semiaxes are along xyz, and are abc respectively. Now the distances pa_1, pb_1, pc_1, may be laid off in the same direction from p or in different directions; so that, in all, four different combinations can be made, either of which will describe the same ellipsoid. But the position of these four generating lines through any assumed point $x_1y_1z_1$ of the ellipsoid is such that their equations are

$$\frac{a}{x_1}(x-x_1)=\pm\frac{b}{y_1}(y-y_1)=\pm\frac{c}{z_1}(z-z_1)$$

Now if the fluid stress $\frac{1}{4}(a+b+c)=or_1$ be laid off along the normal to any plane, *i.e.* parallel to that generating line which in the above equation has all its signs positive, and the other three right shearing stresses r_1r_2, r_2r_3, r_3r_4 be laid off successively parallel to the other generating lines, as was done in plane stresses, the line or_4 will be the resultant stress on the plane.

PROBLEMS IN SOLID STRESS.

Problem 27.—In any state of stress defined by the stresses on three rectangular planes, to find the stress on any given plane.

Let the intensities of the normal components along $x\ y\ z$ be $a_n\ b_n\ c_n$ respectively, and the intensities of the pairs of tangential components which lie in the planes which intersect in $x\ y\ z$ and are perpendicular to those axes be $a_t\ b_t\ c_t$ respectively, *e.g.*, a_t is the intensity of the tangential component on xoy along y, or its equal on xoz along z.

In Fig. 14 let a plane parallel to the given plane cut the axes at $x_1y_1z_1$; then the total forces on the area $\overline{x_1y_1z_1}$ along xyz are respectively:

$$\overline{x_1y_1z_1}.a_1=\overline{y_1oz_1}.a_n+\overline{x_1oy_1}.b_t+\overline{z_1ox_1}.c_t$$
$$\overline{x_1y_1z_1}.b_1=\overline{y_1oz_1}.c_t+\overline{x_1oy_1}.a_t+\overline{z_1ox_1}.b_n$$
$$\overline{x_1y_1z_1}.c_1=\overline{y_1oz_1}.b_t+\overline{x_1oy_1}.c_n+\overline{z_1ox_1}.a_t$$

in which $a_1b_1c_1$ are the intensities of the

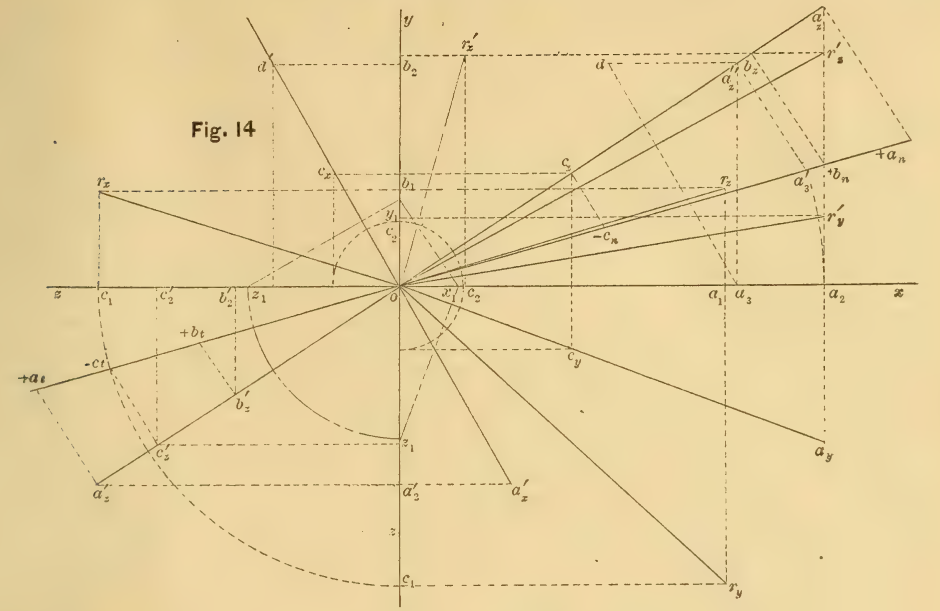


Fig. 14

components of the stress on the plane $x_1y_1z_1$ along xyz respectively. Now

$$\overline{y_1oz_1} \div \overline{x_1y_1z_1} = \cos xn$$
$$\overline{z_1ox_1} \div \overline{x_1y_1z_1} = \cos yn$$
$$\overline{x_1oy_1} \div \overline{x_1y_1z_1} = \cos zn.$$

$$\therefore\ a_1 = a_n \cos xn + b_t \,.\, \cos zn + c_t \cos yn$$
$$b_1 = c_t \cos xn + a_t \,.\, \cos zn + b_n \cos yn$$
$$c_1 = b_t \cos xn + c_n \,.\, \cos zn + a_t \cos yn$$

and $r^2 = a_1^2 + b_1^2 + c_1^2$, therefore the resultant stress r is the diagonal of the right parallelopiped whose edges are $a_1b_1c_1$. In order to construct $a_1b_1c_1$ it is only necessary to lay off $a_n\, b_n\, c_n$, $a_t\, b_t\, c_t$ along the normal, and take the sums of such projections along xyz as are indicated in the above values of $a_1b_1c_1$.

Thus, in Fig. 14, let $x_1y_1z_1$ be the traces of a plane, and it is required to construct the stress upon a plane parallel to it through o.

The ground line between the planes of xoy and xoz is ox. The planes xoz and yoz on being revolved about ox and oy respectively, as in ordinary descriptive geometry, leave oz in two revolved positions at right angles to each other.

The three projections of the normal at o to the given plane are, as is well known, perpendicular to the traces of the given plane, and they are so represented. Let oa_z be the projection of the normal on xoy, and oa_y that on xoz. To find the true length of the normal, revolve it about one projection, say about oa_z, and if $a_z\, a_n = a_2\, a_y$ then is oa_n the revolved position of the normal.

Upon the normal let $oa_n = a_n$, $ob_n = b_n$, $oc_n = c_n$, the given normal components of the stresses upon the rectangular planes, and also let $oa_t = a_t$, $ob_t = b_t$, $oc_t = c_t$, the given tangential components upon the same planes.

Let $a_2b_2c_2$, $a_2'b_2'c_2'$ be the respective projections of the points $a_n\, b_n\, c_n$, $a_t\, b_t\, c_t$ of the normal upon the plane xoy by lines parallel to oz, similarly a_y, etc., are projections by parallels to oy, and a_x', etc., by parallels to ox.

We have taken the stresses c_n and c_t of different sign from the others, and so have called them negative and the others positive.

It is readily seen that the first of the above equations is constructed as follows:

$$a_1 = oa_1 = oa_2 + b_t\, b_z' - c_z'c_2'$$

Similarly, the other two equations become:

$$b_1 = ob_1 = -oc_2' + a_t\, a_2' + ob_2$$
$$c_1 = oc_1 = ab_2' - c_zc_t\ +\ oa_2'$$

We have thus found the coördinates of the extremity r of the stress or upon the given plane; hence its projections

upon the planes of refererence are respectively or_x, or_y, or_z.

PROBLEM 28.—In any state of stress defined by its three principal stresses, to find the stress on any given plane.

This problem is the special case of Problem 27, in which the tangential components are each zero. Taking the normal components given in Fig. 14 as principal stresses we find $oa_2 = a_n \cos xn$, $ob_2 = b_n \cos yn$, $oc_2 = c_n \cos zn$, as the coordinates which determine the stress or' upon the given plane, and the projections of or' are or_x', or_y', or_z', respectively.

From these results it is easy to show that the sum of the normal components of the stresses on any three planes is constant and equal to the sum of the principal stresses. This is a general property of solid stress in addition to those previously stated.

PROBLEM 29.—Any state of stress being defined by given simple stresses, to find the stresses on three planes at right angles to each other.

In Fig. 14 let a simple stress act along the normal to the plane $x_1y_1z_1$, and cause a stress on that plane whose intensity is $a_n = oa_n$, then is $a_n \cos xn = oa_2$ the intensity of the stress in the same direction acting on the plane *yoz*. The normal component of this latter intensity is

$$a_n \cos^2 xn = oa_2 . \cos xn = oa_3,$$

and it is obtained by making $oa_3' = oa_2$, $a_3'a_z'' \parallel x_1y_1$, and $a_z''a_3 \parallel oy$. The tangential component on *yoz* is od' in magnitude and direction, and it is obtained thus: make $a_z''d = a_z''a_3'$, then in the right angled triangle da_3a_2'', da_3 is the magnitude of the tangential component; now make $od' = da_3$. This tangential component can be resolved along the axes of y and z. The stress on the planes *zox* and *xoy* can be found in similar manner, since the tangential components which act on two planes at right angles to each other and in a direction perpendicular to their intersection are, as has been shown, equal; the complete construction will itself afford a test of its accuracy.

Other simple stresses may be treated in the same manner, and the resultant stress on either of the three planes, due to these simple stresses, is found by combining together the components which act on that plane due to each of the simple stresses.

It is useless to make the complete combination. It is sufficient to take the algebraic sum of the normal components acting on the plane, and then the algebraic sum of the tangential components along two directions in the plane which are at right angles, as along y and z in *yoz*.

The treatment of conjugate stresses in general appears to be too complicated to be practically useful, and we shall not at present construct the problems arising in its treatment.

A FEW NOTES ON METHODS OF BUILDING, AND MANUFACTURE OF MATERIALS, IN INDIA.

BY AN ASSISTANT ENGINEER, D.P.W., PUNJAB.

From "The Builder."

MATERIALS, their uses and manufacture, are often so different in India to those of Europe that it may possibly interest some of our readers to know the various kinds and values of timber; the method of manufacture of bricks and lime (generally very primitive), and other materials in use; and to know the many difficulties an engineer has to overcome, which arise purely from the scattered work he has to do, the scanty population (in many places) and means of transport, and other obstacles of an equally minute character.

This article does not aim at going very deeply into the subject, as those who wish to study the matter more closely cannot do better than by consulting "The Roorkee Treatise on Indian Civil Engineering," a book full of practical suggestions and descriptions of the uses and manufacture of materials, &c., in the

Bengal Presidency, besides the "Theory of Engineering," for which it is used as a text-book for the Roorkee College students.

BUILDINGS.

Stone.—The usual material is brick in the plains, and stone in the hills. It is only where stone is available on the spot that it can compete with brick, as the expense of carriage across unbridged torrent beds, and over unmetalled roads, is almost always a bar to its use in any but ornamental work. The red sandstones of the Salt Range, Delhi, and Jaipur, it is true, are carried a long way, but their use is confined to ornament alone, or to pavements of public buildings, and then only sparingly. The stone is all, or nearly all, sandstone, and generally good—in many places very good, and hard, but in others it is very poor, rotten, and worthless, except to be pounded up and mixed with lime. Granite is not found anywhere in the Punjab; neither is limestone used, except in the form of boulders for irrigation dams, &c., where massive work is required. In this form it has been extensively used at Madhopur, the head works of the Bair Doab Canal, where a dam across the Rair has been constructed, to drive the waters of that river, as they debouch from the hills, into the main canal. During the unprecedented floods of August and September, 1875, this enormous piece of work was undermined, and turned in many places completely topsy-turvey, giving ample evidence of the force of the waters, which at other places have spread ruin and desolation over the low grounds of the province.

Bricks.—The next material for the walls of houses of the better class is brick—"pucca" brick, as it is called, the word "pucca" meaning thorough, good, in contradistinction to "kucha," which means exactly the reverse, and is applied to sun-dried or unburnt bricks. The third or intermediate class is called "peela," and is applied to partially-burnt bricks on account of their color, "peela" being used for an ochre color, just such a one as an underburnt brick would have. All three kinds are used in different qualities of work, and in a dry climate, such as India, it is wonderful what a length of time an underburnt brick wall will last when properly protected with mud and straw plaster. Bricks are of all sizes; the old native brick was about 8 inches × 4 inches, and from 1 inch to $1\frac{1}{4}$ inches thick. These are in some places called "Akbare," possibly they were most common during the reign of Akbar (A.D. 1556–1605), under whom a large amount of work was commenced and partly completed. The native brick in common use now is called Lahore, and is about 5 inches × 3 inches × 1 inch. It makes very good strong work, but, as may be supposed, uses a good deal of mortar.

The bricks in use in the Department of Public Works and Railways are the English stock, 9 inches by $4\frac{1}{2}$ inches × $2\frac{1}{2}$ inches or 3 inches; the irrigation brick, which is 10 inches × 5 inches × $2\frac{1}{2}$ inches; and the large brick, 12 inches × 6 inches × $2\frac{1}{2}$ inches to three inches.

Kilns.—The old native kiln or "Pajarvah" is a very cheap though slow style of kiln, and the bricks have one advantage over flame kilns—they are thoroughly annealed. The kiln is V-shaped in plan, an excavation begun in the ground, and at a depth of 2 feet or 3 feet, is continued at an angle of about 1 in 10, until it merges into an embankment formed of the earth excavated. When these kilns were first started their dimensions were not very large possibly, but in many kilns whose lives vary from 20 to 150 years, the excavation at the toe of the V is from 3 feet to 10 feet above the surface of the ground.

The material used is brushwood, and horse or cattle litter, the solid refuse of the cities, &c. The method of loading is as follows :—A layer of light brushwood is laid at the bottom of the kiln, and covered with "oopla," or cow-dung cakes dried in the sun, leveled with litter, then a layer of bricks, two courses on edge of 9 inch bricks, or three of native bricks, and these are covered with litter double the thickness of brick below and damped down with ashes. This goes on until the loading has reached about 12 feet from toe of kiln, where, by the way, the firing begins. The courses of brick are here increased to three, and then four, and at a little distance two tiers of brick and litter are laid, and so on until the kiln is loaded well away

from toe; it is then fired. The kiln is always so placed as to face the prevailing wind, and when lit, the fire is driven forward by the wind. The kiln is set alight by igniting the brushwood at the mouth, and by damping down any place where the fire might burst out too freely, with ashes, the flame is kept in check. The loading proceeds, and as soon as the bricks near the mouth are cool, unloading the kiln is commenced, and in this way unloading is going on at the mouth, firing in the center, and loading towards the end. A large "Pajarvah," 50 feet long, will contain an equivalent to 300,000 of 9 inch bricks, and will take seven or eight months loading and unloading.

The "*Clamps*" present additional facilities for unloading. They vary in size, from the one which contains 20,000 bricks (9 inch size), to the large one which contains 150,000. The fuel is "oopla" (dry cow-dung cakes, about 8 inches diameter and conical, 3 inches or 4 inches or 5 inches in height). The loading is horizontal, with a perceptible dip towards the center. The proportions of fuel are: 1st layer, 2 of fuel to $\frac{3}{4}$ brick; 2d or 3d layer, 2 to 1; and above that less and less, until near the top it is $1\frac{1}{2}$ to 1. A small kiln will turn out bricks in three weeks from firing, and a large one in six weeks. Bricks burnt in litter kilns do not burn so deep a red as those from flame-kilns; they are much harder and better annealed, but they contain more ammonia and discolor much sooner. Clamps are very useful in burning ornamental brick, as the heating and cooling process is so gradual that the fine edges or mouldings are very little injured.

Flame-kilns.—There are a good many varieties of flame-kilns; one or two successful patents have been, within the last four or five years, obtained for their use. The best kiln of the old kind is called the "Lind" kiln, and is about 26 feet by 18 feet, inside measurement, and 12 feet high above the arches. An excavation in the ground, 7 feet in depth, contains the furnace, the same size as the kiln, but divided into two by a wall in the furnace. There are parallel walls 5 inches or 6 inches apart, carried on arches, on which the bricks to be burnt rest. In this kind of kiln large and small wood can be burnt together, even large logs of 1 cwt. to 2 cwt. When properly loaded and fired, the loading occupies two days' firing, 70 to 80 hours, according to season of year. The bricks cool in 25 days, and give an out-turn of 88 to 94 per cent. Each kiln contains 44,000 to 47,000 9-inch bricks.

Other varieties of the same-sized kiln are used; in many there are no arches; the bricks themselves forming arches. That called the "Allahabad" kiln is about 100 ft. × 18 × 12. Its method is rather complicated, and wood, coal, and charcoal are all used during the process. It burns a large quantity of bricks at a time, between 2 and $2\frac{1}{2}$ lakhs, and its out-turn is said to be very good. Coal is not much used in Upper India, and nowhere above Allahabad, owing to the great cost of carriage.

The kiln which is best adapted for large works is the one known as "Butt's Annular Kiln;" it is a very similar one in theory to Hoffman's, but is much simpler, and not nearly so costly to erect. It requires considerable experience before its full capabilities can be developed. The coolies in charge must be all trained men—otherwise it is a failure. The principle of the kiln is simply one which may be called "endless." There are two walls, circular on plan, 12 ft. apart, and having 11 flights of steps, which serve as buttresses, whilst giving access to the top. The bricks are loosely packed in concentric walls, 3 in. or 4 in. apart, and at every four feet arches are constructed, exactly opposite the fire-holes in the external walls. The radius of the inner wall is 75 ft., and each section—*i. e.*, the piece between a flight of steps—contains 8 holes. The method of loading is peculiar, and not easily understood without a diagram. Suffice it to say, that four holes are fired with wood (not over 8 in. diameter) at the same time, and the smoke is drawn out of openings left in the loading, about 20 ft. ahead of the last hole, air being drawn through the already fired part of the kiln. By this means the green bricks are gradually dried, heated, and brought to a white heat, and as gradually cooled after they have been burnt, as there is no escape of heat upward, the top layer being covered with one ft. of ashes. A lakh (100,000) of bricks can thus be burnt with 150 ohms or 5.36 tons of fuel.

A kiln is divided into 12 divisions ; each division, being about 50 ft. in length, contains 23,000 9-in. bricks. It follows that by the time the kiln has been once fired round 276,000 bricks will have been burnt ; about 14 to 15 sections can be fired per mensem. Only about two-thirds of the kiln is loaded at one time—say, about 200,000 of bricks ; unloading goes on at one section, loading a section or two behind, and firing from half to a section behind that, so that even though the loading be interfered with by unseasonable weather, the out-turn can be depended upon for some weeks. The kiln described is circular on plan, but it could, of course, be built elliptically equally well to suit shape or size of ground. There is also a rectangular kiln on the same principle, but it is not one much used. Size of ground is not usually an object of importance as brickfields are, as a rule, some distance away from cantonments or stations, on sanitary grounds. Underburnt bricks are much used in native buildings and in partition walls of 2d class buildings, as they stand very well when not exposed to the atmosphere or damp. Sun-dried bricks are used in very large quantities, both in native buildings and in those built by Government for jails, &c., in dry climates. When properly plastered (mud, chopped straw, and cowdung) and kept in repair, the heavy rains have very little effect on them, but now and then a shower of rain of long continuance will bring the houses down as if they were made of sugar. It is said 8 hours' rain would not leave such a place as Mooltan. During the season of 1875 the whole of the new jail in Amritsur and part of that in Lahore were completely ruined. Both were built of sun-dried brick, and both together represent a loss of some £12,000 to Government. In the author's opinion sun-dried work for Government buildings is quite a mistake, and, though cheap, is very nasty. It cannot be repaired as often as it should be, and, in the long run, costs a great deal.

Concrete is the material for India. What this country wants is a good quick-setting cement like the Portland, and that it has not as yet got. Bricks being obtained, the next requisite is

Lime.—Stone lime is obtainable near the hills, and the average distance from the places where it is made and its destination is, in the Punjab, 30 to 50 miles. It is in many places obtainable only in a slaked condition. Its cost unslaked varies from £1 to £4 per ton. It is generally of a white color, and fat. In fact, the inferior and more hydraulic qualities are not much used, as they could bear less admixture of soorkee, the cheaper material. The limestone is found in the bed of hill torrents, and is washed down from the mountains above. It is never grained, and the boulders are always burnt rough just as they are found. The kilns are V-shaped, and are loaded with the fuel underneath, and are then left to burn themselves out. The fuel is the light brush-wood of the hills burnt quite green. The result is that only about half is burnt properly, and each large lump has a core of imperfectly calcined stone in its interior, which is pure waste, as the lime is always purchased by weight. Fat lime is generally used with soorkee, which is brick refuse pounded fine, screened, and then mixed with the lime in the proportion of 1 lime to 2 soorkee. The latter is a puzzolana, and should be made from thoroughly burnt bricks. Sand is not often used as it cannot be obtained coarse enough, and is, besides, full of mica. It is sometimes mixed with a proportion of soorkee to prevent cracking in plaster, &c.

Kunkur is another lime-producing substance. Kunkur is, it is believed, found only in India, and is generally supposed to be produced by the filtering action of water through coarse soil. The water, of course, contains particles of lime. These are deposited sometimes on the surface and sometimes below the surface of the ground. It is always found in larger quantities near the hills, and at the sides of old water channels than anywhere else, and at Pathankote. About 5 miles from that town there are several places where kunkur is found on the surface, with evident marks of its having been formed around vegetable substances—for instance, a kind of stalagmite, formed around a stalk of grass or reed—and one specimen was shown to the author which distinctly showed that it had been at one time the outer case of a gnarled base of a tree, the impression of the bark being distinctly traceable. The usual kind found is about the size of po-

tatoes, in lumps, in which earth is more or less mixed, but it is also found having the appearance of stone, in layers from 2 to 4 feet thick, and about 3 to 5 feet from the surface of the ground. About Aligurh it is used as a building material, and it has one peculiarity that it hardens rapidly on exposure to the air. From an analysis of kunkurs, near Goordaspur, it appears that the average percentage of carbonate of lime in the specimens was 50 or 51 per cent., and those about Sealkote, 52 to 53. This shows that kunkur is a natural cement, and, though it is not a quick-setting one, it is, nevertheless, a fact that it is considered and treated as a lime by most engineers. Some of the kunkurs require an addition of fat lime, and some of soorkee; but unless the lime is burnt under strict supervision it is very frequently adulterated, and it is now almost universally burnt with charcoal instead of with cow-dung, as it used to be. The usual way has been to load it into clamps with oopla for fuel, but when charcoal was used V-shaped (in section) kilns were introduced, in which the kunkur was either mixed with the charcoal in proper proportions or else in alternate layers of kunkur and charcoal, the lighting being done by igniting pieces of charcoal and then pushing them into vents left at the bottom of the kiln, previously fitted with either charcoal or oopla. The out-turn was fairly good, but kilns of large size could not be employed owing to the precarious nature of the out-turn; sometimes a high wind or fall of rain would either burn a kiln to clinker or make it under-burnt. A plan has been recently adopted which was entirely successful—viz., the clamp system, but with charcoal fuel. Very good results were obtained, and the kiln could be fired when required, or if fired could be protected with mud plaster, until it was necessary to open it. When burnt the nodules are pounded fine, and should be used with a very small amount of water, and mixed with that only just previous to use. The common practice, however, is to mix it with a good deal of water, and to leave it, sometimes for a day or two. In the writer's opinion, this simply ruins it, as he considers it a cement, and not a lime. Pure cement simply laid in a mould and not rammed will, in most cases, harden under water if left to harden in the air for 48 to 72 hours previously. In concrete it makes excellent work, and it has a very nice appearance owing to its reddish grey color.

Floors.—There are, in Indian houses, no second floors—at least, in the upper provinces—and very few barracks have them, so that the floors are, of course, placed directly over the earthen filling in of plinth. They are, as a rule, in Government buildings, of bricks or square tiles 3 inches thick, laid over either a concrete bed $4\frac{1}{2}$ inches thick or over a course of bricks and bats. In private houses they are seldom anything but coarse mortar, hardly to be called concrete. In double-storied barracks the upper floors are $1\frac{1}{2}$ inch planks nailed to joists carried on beams or trusses.

Roof Coverings.—The roofs may be said to be divided into two divisions—flat and sloping. Flat roofs are by far the most common, and trussed roofs are only adopted in large public buildings and barracks for European troops. Flat-roof coverings are usually of the following materials in the North-west provinces:—1st, a course of 12 inches $\times$ 12 inches, or 12 inches $\times$ 6 inch flat tiles, $1\frac{1}{2}$ inches to 2 inches thick, and over this 4 inches of well-beaten "terrace," which is concrete or coarse mortar floated on the upper surface with pure white lime mixed with "goor," or coarse sugar. This is very liable to crack owing to the tremendous power of the sun in the hot weather, and the cooling action of a sudden storm of rain. These hair cracks are a constant source of annoyance and leakage, and require to be constantly filled up with rosin and lime or Portland cement. In the Punjab the flat-roof coverings are of 12 inches $\times$ 6 inches $\times$ $1\frac{1}{2}$ inch to 2 inch flat tiles covered with $\frac{1}{2}$ inch to $1\frac{1}{2}$ inches plaster, well beaten, and 4 inches of earth well beaten, covered with 2 inches of mud plaster, or a composition of mud, chopped straw called bhoola, and cow-dung. These roofs are very cool, but require to have the weeds pulled up before the annual rains, and then replastered. If this is properly done the roofs never leak. A cheaper kind is made by laying thin boards over the joists and then loose bricks and mud as above. Stables and out-houses, also the ordinary bazaar-house roofs, are of

reed mats called "sirki," covered with a coarser reed called "sirkunda," with the mud above that. When beaten, plastered, and kept in proper repair, they do not leak much, but the white ants are, of course, very troublesome, and the reeds have to be renewed every 7 or 8 years.

Tiled roofs are made of flat and half round tiles, and over the joists there are 12 inches × 6 inches flat tiles, covered with 1 inch plaster. Over this the tiles called "Goodwyn" tiles are laid. These are those just spoken of, and 200 are required to cover an area of 100 square feet. The flat tiles are about 14 inches × 12 inches and 1 inch thick, having the sides turned up 1 inch. They are placed side by side in a little fresh mortar, and the half round tiles are then laid in mortar over the abutting joints.

The "Jubbulpur" or "Allahabad" tiles are similar in idea. The former are merely smaller tiles, one set being laid over the other, forming a double roof, very cool it is said, and the latter are the same with the exception of the lower half round, which are demi-hexagons, to enable 2 inches course of flats to be laid evenly and to avoid slipping. Italian tiles are very little used, as also slates: —1st, on account of their cost; 2d, on account of the heat, they being no protection whatever; and, 3d, on account of their being no protection from tropical rain. Slates and shingles are used in the bricks in double layers, where they serve their purpose very well.

Thatching is not now much resorted to, owing to the mutineers in 1857 having set them alight as a first measure towards creating a disturbance. They make the coolest of any roof coverings. Slabs of stone are used in the central provinces at Saugor, but hardly anywhere else.

FOOD *vs.* FUEL—CALCULATION OF THE NECESSARY FOOD FOR A HORSE AT WORK.

By M. BIXIO, President of the Compagnie General des Voitures, Paris.

Translated from "Revue Industrielle" for VAN NOSTRAND'S MAGAZINE.

It is evident that the quantity of food required by a horse depends upon two conditions: his weight, and the work he performs. Upon his weight first, because in order to keep him in good condition, it will be necessary to supply the losses arising from respiration, perspiration, and his internal functions; upon the work that he performs, because all work produces heat and this occasions loss of weight.

In considering the conditions of the life of the animal, we may count three different states: 1st. That in which he does nothing: 2d. That in which he moves about but performs no work: and 3d. That in which he does some kind of work.

The food necessary for his maintenance under these conditions separately we will designate in order: The Ration of sustenance: The Ration of Transportation: The Ration of Work.

The Ration of Sustenance is the food necessary to keep him in good condition, supposing that he remains in the stable.

The Ration of Transportation is the amount of food in excess of the preceding ration necessary to keep up his condition if he moves about without hauling or carrying any load.

The Ration of Work is the amount of food in excess of the two preceding amounts, required to enable the animal to perform some useful work.

We will proceed to show how we can arrive at a determination of the amounts of these several rations, and then will establish a general formula.

A food unit is a necessary basis of such calculations, and the science of physiology must supply our want. It is necessary to determine among the mixture of nutritive elements of the food what ones, by their combination with oxygen in the blood, disengage the heat which is the source of the vital force necessary for the muscular contractions.

From investigations upon this subject made in Germany, England, and France, the conclusion has been reached that the nitrogenous or protein compounds are chiefly instrumental in producing the effect in question. The kilogram of protein has, therefore, been taken as the alimentary unit.

M. Sanson, Professor of Zootechnic, at Grignon, adopting this unit has arrived at the following equation:

$$P=\frac{T}{C}$$

In which P is the protein necessary in a ration, T is the work performed, and C is the kilogrammeters of work produced by a kilogram of protein.

The well known formula of mechanical work is

$$T=F.E$$

in which F represents the force exerted and E the path described. We know also that the force exerted in hauling a load is equal to the load moved, multiplied by the coefficient of traction.

If now we designate by M. the weight of the horse, and by A the quantity of protein necessary to sustain 100 kilograms of his weight when at rest; then if p be the ratio of sustenance we shall have

$$p=M\times 0.01A$$

To determine the work produced by the horse in transporting his own weight to any given distance, we employ the formula T=FE. In this case F is the weight of the animal M, increased by m the weight of his harness, and multiplied by .01B. B being the coefficient of transportation, or the effort necessary to keep in motion 100 kilograms of weight. We have then

$$F=(M+m).01B$$

or

$$T=(M+m).01BE.$$

If we represent by p' the protein of the ration of transportation we shall have in the formula of M. Sanson

$$P=\frac{T}{C}$$

$$p'=\frac{(M+m).01BE}{C}$$

in which m is the weight of the harness or of saddle and rider if the horse carry such.

If now we represent by p'' the protein consumed in performing useful work; by N the weight of the carriage; D the coefficient of traction or the effort necessary to draw 100 kilograms of weight along the proposed road; the formula for work becomes

$$T=N\ .01\ DE$$

and Sanson's formula becomes

$$p''=\frac{N\ .01\ DE}{C}$$

Uniting in a single formula the three different formulas above we have

$$P=p+p'+p''$$

whence by substituting the values determined we get

$$P=M\ .01\ A+\frac{(M+m).1\ BE}{C}+\frac{N\ .01\ DE}{C}$$

in which the three different rations are represented in succession.

This reduces to the form

$$P=.01\left(MA+\frac{E[(M+m)B+ND]}{C}\right)$$

Such is the general formula for determining the quantity of protein for a horse when at work.

If the animal works only on alternate days, then he requires his sustenance ration and so much of the ration of transportation as will supply his necessary movements about the stable or pasture. If the sum of such movements be represented by E′ then the ration for a day of rest would be

$$P=.01\ A+\frac{M\ .01\ BE'}{C}$$

or

$$P=.01\left(MA+\frac{MBE'}{C}\right)$$

The general formula then for the protein required for two days, one of work and one of rest, is

$$P=.01\left(2MA+\frac{E[(M+m)B+ND]+MBE'}{C}\right)$$

which may be written

$$P=.01\left(2MA+\frac{M(E+E')B+E(mB+ND)}{C}\right)$$

In this formula

P=the protein necessary for two days.

M=the weight of the horse.

m=the weight of his harness.

N=the weight of the carriage.

A=the coefficient of sustenance.

B=the coefficient of transportation.

D=the coefficient of traction.

C=the mechanical equivalent of a kilogram of protein.

In order that this formula shall be of use the values of the coefficients A, B, C and D must be determined. This is an object of importance in our industry.

It is necessary to remark here that the above formula is based on the idea that nitrogenous materials in the food are necessary for the production of force.

This theory is disputed by M. Voit, who claims that the consumption of nitrogen is no greater in working than resting, while the combustion of carbon and of hydrogen is greatly augmented.

Prof. Hervé Mangon proposes to establish a formula based on the following facts:

"An animal is a machine for combustion. His food is the fuel and his voidings are the ashes. Analysis of the fuel, and the ashes determines what and how much has been burned."

"The burnt portion contains a determinate amount of carbon and hydrogen, which in burning have produced a definite number of heat units."

"The number of heat units multiplied by the mechanical equivalent of heat will give the theoretical number of units of work in kilogrammeters."

"This, multiplied by the proper coefficient, gives the result in units of work obtained.

In working upon this basis Prof. Magnon remarks that the difference between the winter and summer rations may be taken in account.

This idea of establishing a formula is based on the mechanical theory of heat, and the above propositions indicate that observations and experiments upon the animals themselves are of the first importance.

This is not merely a solution of a purely scientific problem but one of great practical utility to an important industry. It is to determine how we shall best nourish our horses so that they perform their work at the least expense.

The nitrogenous elements of food are the most costly ones and we shall economise if we can obtain the requisite force from the carbon and hydrogen only.

But it may be urged on physiological grounds that nitrogen plays an important part in sustaining the animal, and our general formula, taking account of sustenance, calls for a certain amount of protein; only it may be modified perhaps by determining how much carbon and hydrogen are necessary to produce the useful effect T.

The values of the coefficients in our formula remain yet to be determined.

It is generally admitted that for the purposes of sustenance 30 grams of protein are required for each 100 kilograms of weight of body. Therefore A in the formula represents $0.03k$.

In some experiments upon carrying loads M. Sanson concludes that for the horse a constant effort of 10 kilograms is necessary for each 100 kilograms of weight carried at a trot. B in the formula would therefore equal 10.

Morin's experiments upon traction on roads give—for a coefficient upon a dry pavement, 6 per 100 drawn at a trot and 3 per 100 at a walk. Upon the hypothesis of working at a trot the coefficient D would be 6. From experiments by M. Plessis, an engineer in our employ, made upon our own vehicles and upon the several routes, it would seem that this coefficient 6 is too high by nearly one half.

Finally the coefficient C the most important of all has been a matter of research by M. Sanson, who concludes that one kilogram of protein ought to produce 1600000 kilogrammeters of work.

Consequently C=1600000

We believe for our part that this coefficient which has been calculated from the work of omnibus horses is too high.

We find in Prof. Mangon's work: (Traité du Genie Rural) a calculation which assigns to 258 grams of oats a useful effect of 100000 kilogrammeters. It was obtained by observation of agricultural horses working at a walk.

To produce 1600000 kilogrammeters of work would require $4^{k}.128$ of oats containing 462 grams of protein; less

than half the amount determined by M. Sanson; but it must be remembered that this latter figure is based on working at a walk.

On the other hand we find in the same work, that for the *Cheveux de poste* of Paris that 1 kilogram of oats is required for 100000 kilogrammeters of work. This is equal to $1^k.798$ of protein for 1600000 kilogrammeters, which is much more than M. Sanson's estimate. We see from these different estimates how important it is that we should determine by careful experiment the conditions of our particular service.

Suppose we have to determine the ration of a horse drawing our coupé No. 4 for one day and resting the next. The mean weight of the vehicle and load (carrying from one to three passengers) is 533 kilograms. The mean weight of the horse is $420k$; the harness weighs $14k$. The route is about 50 kilometers. The horse during his day of rest does not move more than 300 meters.

The equation for rations, making the substitutions, becomes

$$P.01=\left(2420\times.03+\frac{50300\times420\times10+(14\times10+533\times6)\,50000}{1600000}\right)$$

which reduces to

$$P=2^k, 364.$$

This is the quantity of protein necessary to give a horse in two days when he works one of them under the above conditions.

If oats alone, (containing 7.93 per cent. of protein) are given to the horse the gross weight of the ration would be $28^k.423$. But other food such as hay, corn, bran, etc. etc., is necessary.

We will suppose there is given to the horse during the two days

5 kilos. hay containing .5055 of protein.
5 kilos. straw containing .1818 of protein.
0.4 kilos. bran containing .0553 of protein.

Total $0^k.7426$ "

This would render necessary for the protein of the oats only

$$2^k.364-0^k.7426-1^k.6214$$

which corresponds to a weight of $20^k.446$

In our tables of rations actually given to our horses (Nov. 1877) we estimate the protein at $1^k.6892$ which would correspond to a weight of oats$=21^k.301$.

We feel assured that our equation has a practical value but that for *general* use, it will be necessary to establish the values of the different coefficients separately for the different kinds of work which horses are required to perform.

Some further experiments are necessary to obtain precise values of the coefficients for the varying conditions of our own service.

But in the above analysis, we have determined the question—upon what basis a good ration should be established, and what elements are to be considered in the calculation.

In treating fully the second part of this question, it will be necessary to determine not only the protein but the proportionate quantities of the other constituents of the food. This would require two more equations to determine exactly the conditions of a good ration.

BUILDINGS AND EARTHQUAKES.

From "The Building News."

Although in this country earthquakes are happily rare, we know that in southern and eastern lands they are of such frequent occurrence that the architect has to take the stability of his structures into serious consideration. Indian and Eastern architecture generally has been considerably modified by conditions due to this cause, and we know that the Italian mediævalist introduced so largely the tie into his arched openings as to sacrifice, in great measure, the motive and beauty of the pointed style. Japan has especially suffered from visitations of earthquakes, and it is not surprising that the engineers and others engaged in con-

struction should pay special attention to the means best adapted to overcome the shocks to which buildings are exposed.

We have before us two pamphlets by Mr. John Perry and Mr. W. E. Ayrton, Professors of Engineering in the Imperial College of Tokio, Japan. In one of these* the authors investigate the effects produced by an earthquake on a structure, especially with regard to the time of vibration. Generally it has been assumed that the shock caused by an earthquake produces an impact upon a building, but recent inquiries have shown that it is a wave of elastic compression in any direction, vertically or horizontally, through the earth's crust. These waves of undulation, if we may so call them, are no doubt transmitted to the surface in a modified manner owing to surface irregularities, such as mountain ranges and geological structure. Rocky strata, of course, transmit them rapidly. But we have to regard an earthquake as an elastic compression in some direction. This being so, it follows that a building is affected by an undulation, or rather participates in the vibration of a point of the earth's surface, which vibration may be mathematically determined, or at least approximately so. If we imagine such a wave of vibration to pass under a large building, such as the Law Courts for example, it is obvious some portions of the structure would be affected in a greater degree than others. The lofty square towers would vibrate slowly, compared with the lower parts, and according to the relative height and homogeneity of the masses would be the amount of vibration each part would share. For instance, in a low building we may fairly assume the time of vibration of the shock and of the structure to be approximately equal, if the parts are of the same density ; but if the building is lofty it will vibrate more slowly. A slowly vibrating structure is necessarily subjected to stresses of a complicated kind, and more severe than those of a quickly vibrating one. It is not difficult to comprehend the truth of this proposition, and Messrs. John Perry and W. E. Ayrton have shown that the stability of structures subjected to earthquakes depends mainly upon the quickness of their vibration, or, in other words, on their rigidity of structure and lowness. A slowly vibrating structure—that is to say, a lofty building—will probably, as our authors say, "get broken in its connections with the foundations, if these be rigidly fixed to the ground ; consequently (and we must here oppose the practice of many architects and engineers) putting a heavy top to a lighthouse, the chimney of a factory or other high building, must certainly take from its stability." As they observe, "it is the relative velocity of the base of the structure, with regard to the other parts, which is the fixed quantity, and therefore that the more massive the structure, the more momentum enters it through the base." An ordinary Japanese two-storied house, with its heavy roof, it is supposed, takes four seconds to make a complete vibration, the restoring forces which bring the structure back to its normal position being due to stiffness of the joints, and to the fact that the house is not rigidly connected with the ground. It will surprise the English architect to learn that the Japanese houses are without the foundations we are accustomed to use ; the vertical posts rest on detached stones, and there are no diagonal braces. Thus the building can be displaced from its position of equilibrium by any shock without fracture occurring. There is a "viscous resistance," as the authors term it, to the motion, caused by the various joints, and such resistance diminishes the motion and adds to the safety of the building. Particular stress is laid on this viscous resistance of the joints, and also to the absence of diagonal pieces to lessen the strains. The Japanese temples are considered pretty secure against shock, as they are buildings of slow vibration, and have a great deal of viscosity in their joints. It must be borne in mind that a rigidly connected foundation is independent of the mass of building, and the shock tends to displace at any weak point or surface of contact between different portions. All non-homogeneous buildings have some parts only capable of slow vibration compared to others. The authors justly say that there is a best method of constructing buildings in an earthquake country: this obviously consists in constructing the lower parts of the

* On Structures in an Earthquake Country. By John Perry and W. E. Ayrton, Professors in the Imperial College of Engineering, Tokio, Japan.

building with yielding material, so that the shock from an earthquake may be reduced in intensity and the vibration of the upper part diminished. A rocky or rigid foundation, on the other hand, transmits the vibration or momentum undiminished to the upper parts. Again, a foundation of yielding timber or some soft elastic substance would form a cushion by means of which the time of transmission of the momentum due to the shock may be increased. The authors point out it is desirable to keep houses built of ordinary wall thicknesses, with brick and common mortar, as low as possible—at most not more than two stories high; but if good cement be employed instead of bad mortar then their height may be safely two or three stories. Another point is the horizontal vibration of the ground. This causes a kind of shearing stress in the joints which mortar cannot transmit, and it is desirable, therefore, to make the joints rigid in cement so that the walls may resist a sliding as well as a crushing stress. No doubt we have here a strong argument in favor of cement concretes for building walls in earthquake countries. At any rate it is laid down that the most suitable structures for these contingencies, if of stone, are those built of large stones set in good cement with walls of considerable thickness at the base, diminished gradually in proportion to the mass and height of the building, and we have a strong presumptive argument in favor of pyramidal buildings. As timber has greater tensile resistance to shock, and as the mass of timber in a building is small, a building of this material is even more desirable if constructed with strong joints, while wrought iron and steel have still stronger claims in these respects. Another hint is given—namely, that timber structures should not be too rigidly fastened to the earth. Without going into the calculations of the times of vibration of different buildings given by the authors, as regards shape and height, it is obvious the conclusions drawn by them are convincing; and that, to insure stability in structures liable to shocks, the relative vibrations of the parts of the structure of any given material must be taken into account. Thus, high chimneys, such as many engineers have erected recently, crowned with heavy cornices, are unsafe in a country like Japan: for, as the authors show, the period of natural vibration of a chimney 150 ft. high and 10 ft. square is about 2¼ seconds—a period much too slow to be safe when connected with the walls of a building of less height and consequently of less vibration.

We here turn to another very interesting paper read by the authors before the Asiatic Society of Japan,* in which the motion caused by an earthquake is investigated. The principle our authors set out with is that it is possible to read an earthquake message by the motion of a body attached to the earth by springs. Thus "the centre mass of a body fastened by means of springs inside a metal box rigidly attached to the earth has in certain cases motions with respect to the box itself which in miniature with great exactitude represent the motions of a point of the box during the earthquake." Here we have a self-evident principle upon which an apparatus for recording vibration can be constructed. Without diagrams it is difficult to convey a correct idea of the seismometer of Messrs. Perry and Ayrton. But we may describe it briefly as a strong iron case rigidly fixed to the rocky crust of the earth, with a leaden ball of 400 lbs., supported by five strong spiral springs, four of which are horizontal and one vertical, all having the same period, so that if there were no friction the ball would describe an ellipse when freely vibrating. To record the different horizontal movements there are three arms with pencils; these are made to press by means of spiral springs on a band of paper moved horizontally by clockwork. By these and other means an automatic register of the motion of the earth is diagrammatically made, and these diagrams assume irregular spirals on the paper. Thus the position, velocity, direction, and acceleration of the ball at any moment is recorded, and therefore the motion of any point upon the earth's surface is also registered. Professor Palmieri and others have invented electro-magnetic seismographs, to record earthquake vibrations and intensities, but the exactitude of the records made has been questioned by Mr. Mallet and other authorities in the science of

* On a Neglected Principle that may be Employed in Earthquake Measurements.

seismometry. We may simply add that the authors propose to place three of their instruments on the plain of Yedo, with clocks in telegraphic communication, by which means the vibration and motion of an earthquake-wave could be determined. We only hope the ingenious authors will be assisted in their experiments by the Japanese Government, and that facilities to perfect their instruments will be afforded them in the interests of science and humanity.

THE ACTION OF BRAKES.

From "English Mechanic."

The remarkable and unexpected results obtained during the elaborate experiments with railway brakes, made a few weeks ago on the London and Brighton line, formed the subject of the paper read by Captain Douglas Galton, at the meeting of the Institution of Mechanical Engineers held in Paris. These experiments form the first of a series which it is intended to make with the view of ascertaining (1) the actual pressure required to produce a maximum retardation of the revolving wheels at different velocities; (2), the actual pressure exerted by the different forms of continuous breaks now in use; (3) the time required to bring the break-blocks into operation in the several parts of the train; and (4), the retarding power of the existing continuous brakes, tested on trains running under similar conditions of weight and speed. From the enumeration of these heads it will be readily understood that when completed, we shall have the most important contribution to the literature of the brake question which has hitherto been made; and the first instalment, contained in Captain Galton's paper, is sufficient evidence of the probable value of the series. The experiments described were undertaken to ascertain the co-efficient of friction between brake-blocks and wheels and between the wheels and rails, both when the wheels are revolving and when skidded. It is scarcely necessary to insist on the importance of ascertaining by actual test the exact value of a co-efficient upon which the whole system of brakes depend; and the engineering world is much indebted to the London and Brighton Railway Company for the manner in which they have taken up the question and facilitated the carrying out of the experiments. The experimental van and the recording apparatus were designed and constructed by Mr. Westinghouse and Mr. Stroudly respectively; but for our present purpose it is unnecessary to give a description of the means taken to obtain the results. The latter are unquestionably as correct as ingenuity and care could make them, and if they are remarkable, they serve to show that it is the unexpected that always happens. The experiments under notice were made at the end of May near Brighton, the first day being dry the second stormy, and the third fine, with showers. There was thus a sufficient variety of weather to render the experiments of more value than they might have been if made under uniform conditions, but there was not time to collate all the results before sending in the paper. Captain Galton, therefore, exhibited only a few of the diagrams taken, but these were of so remarkable a character as to excite the keenest attention of the engineers present. In experiment No. 15, May 28th, the brake-van was slipped when traveling at the rate of 40 miles an hour. The pressure on the brake-blocks remained nearly constant during the experiment, and being greater than that required by the co-efficient of friction between the brake-blocks and wheels due to velocity, the friction increased so rapidly as to cause the wheels to skid immediately. The friction at once decreased rapidly, but rose again as the speed diminished, attaining the maximum as the train came to rest, which it did after many jerks in 12½ seconds. In experiment No. 16, May 28th, the van was again slipped—the speed being 46 miles. The pressure of the air was less than in the previous

experiment, and it was gradually diminished during the experiment; consequently the pressure on the blocks was correspondingly reduced. At first the friction between blocks and wheels decreased slightly, but, when the velocity diminished the friction increased rapidly and the van came to rest without a jerk in 12 seconds. Thus the quicker stop was made by the revolving wheels which originally were traveling at a higher speed than in the case of the skidded wheels. This effect was exhibited in a decided form by experiment No. 3, May 28th, in which the speed was 44½ miles. The pressure applied to the blocks was sufficient to skid the wheels at once, and the diagram shows that the co-efficient of friction between the blocks and the wheels decreased immediately after the skidding and did not rise until the end of the experiment, while tractive force on the draw bar, at first increased by the act of skidding, largely decreased as soon as the wheels were held by the blocks. In experiment No. 3, May 29th, the engine and van were brought to rest from a speed of 39 miles an hour. The air was allowed to escape from the cylinder through a small hole after the the brakes were applied, so that the pressure decreased during the whole experiment. The diagram in this case shows that the retarding force due to the pressure of the blocks was at first diminished until the reduction of velocity reached the point where the increase in the co-efficient of friction was sufficient to overcome the effect of the diminished pressure applied to the blocks. At this point the retarding effect was increased, and the wheels were skidded. The curve immediately rose in a nearly vertical line showing that the co-efficient of friction became very great as the wheels came to rest—the time during which the wheel was partly rotating, partly slipping being almost inappreciable. Immediately after the rise, the curve fell to a point far below its original position. Thus showing that with skidded wheels there is a great diminution in the retarding effect of the brakes. As the velocity continued to decrease the curve steadily rose, thus showing that the co-efficient of friction between the rails and skidded wheels increases as the velocity diminishes. At the moment of coming to rest the co-efficient of friction became very great. The results obtained in these experiments may be taken as a fair sample of the series; from which we learn that the application of brakes to wheels does not appear to retard the rapidity of their rotation, but when it falls below that due to the speed at which the train is moving, immediate skidding is almost inevitable. The resistance resulting from the application of brakes without skidding is greater than that caused by skidded wheels. During the moment of skidding, the retarding force increases enormously, but immediately afterwards falls to less than that what it was before skidding. The pressure required to skid is much higher than necessary to hold the wheels, and appears to have a relation to the weight on the wheels themselves as well as to their adhesion and velocity. On this point Captain Galton says:—"It would seem that the great increase in the frictional resistance of the blocks on the wheels, just before and at the moment of skidding, due to the increase in the co efficient of friction when the relative motion of the blocks and the wheels become small, is what destroys the rotating momentum of the wheel so quickly". With constant pressures the friction between the blocks and the wheels increases as the velocity decreases, until, as the experiments proved, the wheels are skidded. But it was also discovered that in order to obtain the maximum retarding effect the wheels ought never to be skidded, but the pressure on the wheels should at all times be just less than is required for skidding. In order to effect the desired result, then, the pressure between the blocks and wheels ought to be very great when first applied, gradually diminishing as the train comes to rest. Such an outcome from these experiments discloses the fact that all the hand-brakes, and most of the continuous brakes, have been designed to suit conditions which do not exist in practice. The old saying —you can do no more than skid—is shown to be utterly erroneous, and the most successful brake is that one, the inventor of which has unconsciously as it seems, grasped the true principle.

That the skidding of wheels is not the best way to stop a train has been known and urged persistently by some railway

men, and the drivers and guards on most lines have orders to release the brakes when the wheels skid; but, until these experiments demonstrated the fact, not a few drivers and others, engineers amongst them, firmly believed that the skidding of the wheels was the readiest method of stopping. It has been objected to mostly because of the wear of the tires—flat places being highly objectionable. So long ago as 1846 Mr. Gooch, while connected with the South Western Railway, issued a rule to his men that wheels were not to be skidded, and if skidding did take place the brakes were to be immediately released and applied again. Mr. Tomlinson said that every practical engine-man knew that the skidding of wheels was a great mistake; but we venture to think that Mr. Tomlinson need not travel far to find plenty of practical engine-men who would argue the point with him. The gentleman who preceded him in the discussion, Mr. Haswell, expressed his surprise at the results of the experiments described by Capt. Galton, as the Newark trials had led the commissioners to form a contrary opinion as to the value of skidding. Mr. Brown, of Winterthur, speaking from practical experience on lines of heavy gradients in Switzerland, declared that if the wheels were skidded much of the retarding force was lost. Mr. Yeomans said that when the vacuum brake was first applied on the Metropolitan a vacuum of 15 inches (?) was found to skid the wheels. The drivers were, therefore, ordered not to exceed twelve inches. He controverted the opinion that the greatest pressure ought to be applied first, and thought that a sudden application of brake-power destroyed the wheels. Unfortunately no reasons were offered for these opinions, save that Mr. Yeomans had seen wheels that had been destroyed by the sudden application of the Westinghouse brakes. He considered that Capt. Galton's experiments had only confirmed what was well known, and that, to obtain any useful information, experiments extending over many years of actual service were necessary. The companies, however, it must be remembered, have had the hand-brake in use for many years, and it has been left to persons not specially connected with railway work to point out that the hand-brake is radically wrong—for, as every one knows, it is impossible to always avoid skidding with it. In view of that fact, and of the statement that the evil effects of skidding were well known a quarter of a century ago, it does not say much for the inventive skill of the profession that hand-brakes were not long ago improved off our trains. The explanation of the diminished retarding force when the wheels are skidded is most likely that given by Prof. Kennedy, though it might be worth while to study the question experimentally by means of heavy weights resting with a small surface on a metal rail. As long as wheels revolve, says Prof. Kennedy, the surface in contact with the brake is continually changing, so the tire does not become highly polished, but directly the wheels are skidded there is theoretically only a point, and practically only a very small surface, taking all the friction between the rail and the wheel. This surface must be almost instantaneously polished, and the wheel consequently slips along with the least friction possible between it and the rail; for, as is shown by the experiment, the friction increases as the velocity decreases. The paper has now, however, drawn attention to the subject, and it is to be hoped it will be worked out in a thoroughly scientific manner. Capt. Galton deserves thanks for what he has already done, and it is not too much to expect that the companies generally should afford facilities for carrying out further experiments.

The discovery of an extremely simple and cheap means to protect houses from being struck by lightning has recently been announced in a French agricultural paper. This consists in the use of bundles of straw attached to sticks or broom-handles and placed on the roofs of houses in an upright position. The first trials of this simple apparatus were made at Tarbes—Hautes Pyrenées—by some intelligent agriculturists, and the results were so satisfactory that soon afterwards eighteen communes of the Tarbes district provided all their houses with these bundles of straw, and there have been no accidents from lightning since in the district—at least, so says *Nature.*

IRON AS A BUILDING MATERIAL.

From "The Architect."

Using a popular formula of speech, it is often said that iron is the material of the future. The fancy of the philosophic builder is supposed to run over a hundred instances in which the more commonplace substances used in construction are found wanting. Visions of what might have been if ingenuity had not been hampered in its enterprise by the conditions attaching to mere stone and brick, timber and boards, are supposed to overwhelm his mind. He finds rest in the contemplation of the Crystal Palace, the St. Pancras roof, the Britannia Bridge, the Vienna dome, perhaps the *Great Eastern*, the *Devastation*, and the *Thunderer*. "Ah, well!" he reflects, "iron is the material of the future; the time will come, although I shall not live to see it, when a gentleman will run his iron house down to his place in the country by rail in August, and up again to the Belgravia of the day in February; when balloons of No. 40 or 50 gauge sheet will travel daily between London and New York; and when a new St. Albert's Cathedral, in a central situation at Wimbledon, will be built of Professor Barff's best black oxidised." Professor Barry, for instance, of the Royal Academy, who officially might not have been expected to look so far ahead, is amongst others as enthusiastic upon this point as could be desired. The architecture of the world in the future can scarcely fail, he says, to be modified by our scientific knowledge of iron, which as a building material has been almost discovered by the present generation. From the Egyptians—to whom it is, of course, impossible not to allude—we have no doubt much to learn; from the Greeks also. But had the Romans known as much about iron as we do they would have been able to teach us something. The mediæval builders also would not have clung to their primitive arcuation if they had known about iron. In the present day architects are too considerate of the past; if they would but consent to let engineers help them in construction in exchange for similar assistance in decoration—in short, iron would then become the material of the future.

The Conference of Architects, which was held last week, seems to have dealt with iron, if nothing else, seriously. Professor Barff explained his system of creating upon the surface of this metal—as the weather does upon certain others, such as lead and zinc—a preservative oxide. Under the presidency of Mr. George Godwin a variety of fireproof inventors discoursed to each other upon the protection of iron from its inevitable destruction in great fires. Mr. Barlow, C.E., described at another meeting the construction of an iron roof recently designed by him; and thereupon Mr. E. M. Barry wound up the whole with the thoughtful reflections we have quoted. If nothing comes of all this, it cannot be said that architects have not at least, and at last, taken the subject into consideration.

But there are people of still more careful habits of thought, who will shake their heads, and say that nothing can come of it after all. Indeed, when Mr. Barlow, speaking incidentally of the great Tubular Bridge of Robert Stephenson, tells us of one thing being perfectly clear—that no such structure will ever be built again; and when Mr. Carroll, of "unpractical romantic Dublin," tells us how he and an engineer companion, as they traveled along it, shook in their shoes with a great fear lest the wonder of the world should shake itself and all that was within it forthwith into eternity, by reason of the "tons upon tons" of ruinous red rust shaken perpetually from its dreadful flanks; these authorities are indicating pretty clearly that the scientific mind is already being rapidly disillusioned, and that before long there will be no one left to believe in the perfectibility of iron buildings, unless it be such a one as a professor, whether of architecture or of chemistry, in the Royal Academy.

It is by no means a paradox to say that Nature does not undertake to supply man with building materials. He is permitted, no doubt, to hew stone from

the rock, and to fell timber in the forest, and it must be acknowledged that these accidental products have gone very far indeed to serve the builder's purposes; but the not unreasonable theory that the artificial objects of building must be taken to point to the use of correspondingly artificial materials is one that has in reality been exemplified from the most primitive ages—in the invention, for instance, of such an odd thing as brickwork; and when we are led in modern times to try what can be done with iron, it is the self-same principle that is manifesting itself—building is being driven by its own essential artificiality to seek artificial materials. In other words, reasoning upon the matter *a priori*, if not otherwise, we are entitled to say that Nature cannot be expected to provide to the architect and the engineer, more than to the machinist, anything beyond the crude components out of which he shall make for himself such materials as shall best serve his ends. But however this may be, it is plain enough that in this respect the line must be drawn somewhere which shall divide the practicable from the impracticable; and it is, perhaps, more than probable just now that that line must be taken to exclude iron in a very great measure from the list of true—that is, permanent—building materials, and to leave it almost entirely to mechanical engineering and other such manufacturing art as its more proper province. Such perfectly artificial materials, for instance, as brick, terra-cotta, artificial stone, concrete, cements and plasters, lead, glass, paint, and so on, answer the builder's artificial purpose admirably. There are, likewise, many appliances of building, akin to mechanical work, in which iron is almost as invaluable as it is to the mechanician generally. There are also certain incidents of building in which, for even structural features, iron comes to take the place of timber with excellent effect, as in columns and girders judiciously introduced. But here it would really seem as if we must stop for ever; crude as natural stone may be, iron can not take its place, and, fatal as may be the effect upon timber of the dilapidation of centuries, the case of iron as a substitute is much more serious within much shorter periods of time.

The employment of iron in ordinary building is to be fairly described as being altogether that of an equivalent for timber. The principles involved—those of the post and girder, the bent arch, the truss, and whatever else—are precisely those of timberwork, and a sheet-iron covering merely takes the place of boarding. Bolts and rivets represent screws and nails, and even the angle iron has its prototype in the work of the joiner. The only advantages derived from the use of the metal are in respect of strength and lightness, complexity of scientific design, and minute precision of calculation. Apart from these considerations, we might just as well even now be dependent exclusively upon our old-fashioned fir and oak—old-fashioned, no doubt, but still as far as ever from being obsolete. Where, then, is the great drawback in the use of ironwork? Why is it that it it has not during the last fifty years, since the invaluable article of poor Cort's invention—rolled iron—has become so intimately available and so cheap, acquired an absolute ascendancy over the timberwork which seems by its side so clumsy and unmanageable? The answer may be given in single word—Rust. Of all metals, perhaps this, the most useful in a thousand ways, is the worst to wear against the weather. Moisture in the simplest form is its deadliest enemy. Lead or zinc, for instance, as we have already hinted, when exposed to atmospheric action, becomes coated with an oxide of itself, which renders paint useless as a preservative; but iron, in forming its oxide in the same circumstances, develops a process of absolute disintegration, and falls rapidly to powder, and no preservative process yet known will protect it. Common painting, it has to be borne in mind, is simply the act of attaching to the surface of any more perishable material a coating of carbonate of lead as a material less perishable and easily renewed. Not merely oil paint, however, but the application of a coating of zinc, a much more scientific and successful invention, is scarcely of any permanent use in practice; and if we fail in protecting our ironwork from disastrous rust, we fail in making it really serviceable as a recognised building material. Not only the architect, but the engineer none the less, must ac-

knowledge this; and when the architect is obliged to discard iron in so great a measure, it becomes a question of time when the engineer also may have, however reluctantly, to regard it with universal anxiety.

Supposing that the general surface of the iron may, by the judicious application of some specially judicious coating, and its frequent renewal, be kept quite free from oxidation, this unfortunately does not help us after all. It is the peculiarity of ironwork that it is never at rest. It expands and contracts considerably under ordinary changes of temperature. It vibrates still more considerably under ordinary pressures. If, therefore, we are obliged to put it together by means of such a process as riveting—if, in other words, we have to make it up of small pieces pinned together—then are these considerations which at once appear with reference to rust. A thousand joints offer access to the microscopic influence of atmospheric moisture in a thousand places. A thousand pins—call them by what name we please—are in one way or another constantly moving under strain, however minute their movement. Nor is this all; for, in the very act of putting the work together at first, if any preservative had been previously applied to the surfaces that are now brought into contact under the force of the smith's hammer, it is only too plain that at the very weakest points of all the preservative has been abraded quite away, and the veriest nakedness of the metal exposed again to the most direct and rapid creation of rust. Not only oil paint, but what is called the galvanized coating of zinc, is obviously immediately rubbed off whenever a rivet is hammered, or even a bolt tightened by a wrench. What makes the case still worse is the circumstance that oxidation, when once begun, will insidiously continue to progress even under the preservative coating. It is easy, then, to see that, of all materials as yet employed in building, iron is in practice the most incapable of defence against a peculiarly disastrous decay produced by the most commonplace, most universal, most unavoidable, and most insidious process of attack. The invisible and motionless vapor of the air, which nourishes the world, is the inevitable and special destroyer of the mightiest substance manufactured by the ingenuity of man.

That these reflections are a serious check to the aspirations of building science it is needless to deny, but enough has been said to show even to the meanest capacity that, so far as it has yet gone, iron is emphatically not the material of the future.

THE BRITANNIA BRIDGE.

From "The Engineer."

At a recent meeting of one of the architectural societies it was gravely stated that the great bridge of Stephenson's was rusting away. The process of decay was progressing with alarming rapidity; consumption, in its worst form, had seized upon the noble structure; the disease was incurable, and its days were numbered. These statements publicly enunciated naturally somewhat alarmed outsiders, who began to entertain the notion that they might perhaps be correct, and that, at any moment, the Straits of Menai might engulph the Britannia Bridge and the Irish mail, passengers and all. We trust the protest of the engineer-in-chief of the London and North Western Railway, published in our daily contemporaries, has dissipated so absurd and unfounded an idea. It is just possible that it may have occurred to some one that since many old stone bridges over the Thames have disappeared, and Waterloo Bridge, upon excellent authority is shortly to do the same, that it was high time, upon the principle of fair play, that an iron bridge ought to begin, at any rate, to show some signs of decay.

The Britannia tubular bridge belongs to a particular class of structures of which we shall never see any more ex-

amples. As it is, that class has been reproduced, we believe, in only two instances; one of these is the Victoria Bridge at Montreal, and the other, a bridge of the same name in Australia. There can be very little doubt that the idea of the tubular form was either suggested to Stephenson, or if conceived upon other grounds, he was confirmed in the idea by the information he received from Fairbairn with respect to the strength of iron ships. An iron ship, allowing for the difference in form and other details of design, represented then as it does now a complete iron tube, if we regard the deck as constituting the upper boom. If, again we imagine the ship supported, as no doubt she often is, near each extremity upon the crests of two waves, she becomes an absolute tubular girder for the time being. It must not, however, be supposed that because we shall not construct any wrought iron bridges upon the model of the Britannia Bridge, that we thereby constitute any argument against its original merit, its present security, or its future durability. We are not likely to build any cast iron bridges in accordance with the design of Southwark Bridge; but that does not prevent that structure from possessing the largest span in cast iron in the world. The nearest approach to it, with the exception of the Sunderland Bridge over the Wear, are the seven arches of the bridge of Tarascon over the Rhone, which have a span of 203 feet each. It is now nearly thirty years since the Britannia tubes began doing their duty, and it is not so much a question whether they have suffered during that period from those causes which ultimately weaken and deteriorate every artificial structure, as whether the amount of deterioration is accurately known and provided for. Those who have read the letter of Mr. Baker, published in a daily contemporary not long since, will be assured that with respect to both these points, the condition of the Britannia Bridge is in every way as satisfactory as when the tubes were first erected.

Having touched upon the subject of the corrosion and consequent deterioration of iron bridges, it may be of interest to our readers to inquire generally a little further into the matter. As it is with timber, so it is with both cast and wrought iron. A great deal depends upon the quality of the material itself, and the medium which surrounds it. Some descriptions of timber will last, if wholly and constantly immersed in water, practically speaking, for ever. Timber piles have unquestionably been found perfectly sound after an immersion in water of over 500 years. The statement that the piles of Trajan's bridge were discovered perfectly sound after the lapse of sixteen centuries, must be received with caution. Other descriptions of timber will last a long time in a dry atmosphere, but not when exposed to damp; and very few indeed will stand exposure to alternate wetting and drying. Cast iron, again, has been found, in one locality, to be so soft after some years' immersion in salt water, as to be readily cut with a knife. In another locality of a similar nature, it has remained for fifteen years as sound as when first immersed. This case scarcely applies to the kind of deterioration under notice, which is limited more particularly to wrought iron.

The corrosion of wrought iron, to which structures in the position of the Britannia tubes are subjected, consists, practically, in the oxidation of the various bars and plates, and of the ironwork generally of which the tubes are built up. The oxidation takes the form of rust or scale, which sometimes falls off, and at others is removed at the periodical cleaning and repainting of the ironwork. Obviously, every successive formation and removal of this scale diminishes the original thickness of the iron, and it becomes a mere matter of time until that thickness is reduced to zero. The remedy, as regards maintaining the strength of a wrought iron bridge, clearly consists in either preventing the formation of the scale or allowing for it. No means have yet been discovered which will completely secure the first of these objects, although much may be done towards it. It is not difficult to carry out the latter plan. If the rate of oxidation for one, or any number of years, can be ascertained, even with approximate accuracy, the necessary extra allowance of material can be easily provided. It will first be requisite to determine what that rate is, more especially

as it varies with the material employed. If the medium be damp air, the relative oxidation of steel, wrought iron, and cast iron is about 1.12, 1.08, and 0.84. It has been inferred from experiments that the oxidation, or depth of corrosion of ironwork when exposed to clear sea-water, increases at the rate of 0.00215 inches of thickness per annum, which is equal to nearly $\frac{55}{250}$ inches in 100 years, or to $\frac{55}{128}$ inches in 200 years. There is not any plate in the Britannia tubes whose destruction would jeopardise the safety of the bridge which has a thickness less than $\frac{1}{2}$ inch or $\frac{64}{128}$, so that upon the assumption we have made, the tubes would, in about 232 years, be entirely corroded or rusted away. There is just one little saving clause in the case, which might add perhaps another fifty years or so to their existence—it is that the scale of oxide might adhere to the iron, and thus very considerably diminish the rate of oxidation of the remainder of the iron.

The Britannia Bridge is placed at an elevation of about a hundred feet above the sea level. It is, therefore, apparent that the supposition that the ironwork is exposed to the immediate action of sea water is not correct, and that the tenure of life assigned to it upon that supposition is too short. Let us consider the tubes, then, exposed solely to the action of rain or fresh water. Under these circumstances, and making the calculation from the same datum, the annual depth of corrosion of the iron will be 0.00035 inches, or at the rate of rather less than $\frac{9}{256}$ inches in 100 years, or $\frac{9}{128}$ inches in 200 years. The life of the tubes under these conditions would be about 1400 years. But this supposition is probably as much too favorable for the bridge as the former is unfavorable. The tubes, although not actually wetted by the salt water, are, nevertheless, acted upon to some extent by its saline qualities. They would be exposed to the action of rain, which would wash away the rust, and constantly expose new surfaces for oxidation. Under the most unfavorable circumstances the bridge would, however, last at least 100 years. Such a line of reasoning takes no account, however, of the conservative powers of paint, which, if of good quality, and applied with sufficient regularity to surfaces which would otherwise be denuded, may prolong the life of an iron structure almost indefinitely. Making all allowances, therefore, it is not too much to say that, with common care, the Britannia Bridge would last 150 years without any heavy repairs.

It is well known that the greatest possible skill and prevision were exercised in selecting the iron and executing the workmanship of the Britannia Bridge. At the same time, it is very possible that some parts of it are, either from greater exposure or other causes, more liable to corrosion than others, and might, therefore, be sooner deteriorated. In this case nothing is easier than to cut out the damaged and weakened plate and rivet on a fresh one. In fact, the whole bridge might be gradually reproduced piece by piece in this manner without affecting the integrity of the design or its practical efficiency. The parts of the structure most liable to corrosion are the outside plates composing the upper and lower booms and the sides, and these are precisely those which are the easiest to replace. The complicated and troublesome portion of the work lies in the ironwork of the top and bottom cells. A very recent examination has proved all the ironwork in these parts of the tubes to be in a perfectly sound and unimpaired condition. Experiment has established one more fact in connection with the corrosion of iron structures which is worth mentioning, as it bears immediately upon our subject. It is that iron when subjected to repeated vibration does not corrode with the same rapidity as when in a constantly quiescent state. The number of trains passing daily and nightly through the Britannia Bridge do not allow it much actual rest. If to these we add the expansion and contraction, and the influence of winds, slight although their effects are, we doubt if the tubes are ever in a state perfectly free from vibration. Wrought iron bridges are comparatively of too modern a date to afford any reliable information respecting their ultimate durability. It will require another fifty years before the problem will be in a fair way of being solved, and we may, therefore, be excused if we decline to say precisely how many hundred years the Britannia Bridge will last.

SOME PHENOMENA EXHIBITED BY THE COMPASS IN MINING SURVEYS.

By WILLIAM LINTERN.

From "Engineering."

The general opinion of the action of the magnetic needle used to be, and, I think, generally still is, that, unless diverted by purely local and accidental sources of attraction, and which are, therefore, removable, the needle will adjust itself parallel with the magnetic meridian of the place and time in all positions; and that, consequently, when free to move under such conditions, it will in a series of different positions maintain a true parallelism.

Several years ago, having occasion to make a survey of a certain colliery of considerably over a mile in length, and with particular accuracy for a definite purpose, I first made the survey with the needle, fixing it to the zero of the instrument each time, and working off the limb, and reading to minutes; I next made a check survey over the same lines without using the needle further than to get the magnetic bearing of the first line, so as to insure—as I supposed I should have—the same parallelism as before in the previous survey; after the first line I used the instrument simply as an angleometer by setting the limb with the precise previous reading back each time upon the back light, and I simply liberated the needle at each station for the purpose of observing its action under those circumstances; and, to my surprise, I soon found such a variation in the parallelism of the needle, as the work progressed, that I came to the conclusion that an error in manipulating the instrument had been committed; by re-observations of the lines I found this was not the case, and I determined to proceed again in the same way throughout the whole length of the survey—in all over 40 lines—and particularly to watch the action of the needle.

In the majority of the lines I found a marked variation of the needle bearing, and in scarcely two successive positions would it assume precisely the same parallelism; sometimes it varied in the aggregate of a number of lines to as much as 2° 30′ on one side of zero, then it would gradually return back again towards zero, and then progress to a considerable variation on the other side,—thus oscillating to and fro several times over the zero as the work progressed. The successive angles of the second survey were reduced on the base of the magnetic bearing of the first line, taken as before explained, and both surveys were carefully plotted off the same meridian line and position; and the result was that on comparing the two series of lines, although there was a *general* agreement in the direction of the corresponding parts of the surveys, there was yet a distinct minute difference, and such was the divergence as the laying down of the surveys progressed, that the final positions were 120 links apart; and, taking into account the fact that a straight line drawn from the initial to the final position or station measured 70 chains or thereabouts, the magnetic bearing of the first line of the angular survey, when compared with the average of the readings of the magnetic survey, showed that there was an error in one or the other equal to 59′.

Satisfied that the variations which I had here so carefully observed were not the result of what are generally called removable causes, peculiar to this particular colliery, I have from time to time over a number of years, and with different instruments, and under a variety of conditions both on the surface and in the mines, taken steps to observe the peculiarities of the working of the magnetic needle; and in the result I have found that a variation, more or less, is very general—more general indeed than an accurate parallelism is.

I will here give some examples to show this variation more forcibly.

Ex. 1.—In a heading crossing the pitch of the strata from one vein of coal to another (technically called a "cross-measures" heading), a straight line was carefully ranged out, and at nearly equal

distances apart, over a total length of about 60 yards, the instrument was set up five times in correct alignment, and the magnetic bearing of the lights purposely fixed at the two ends of the line were observed from each position; and the result was, that what is generally supposed would have been five similar readings, turned out to be as follows, viz., 174° 3′, 175° 21′, 174° 45′, 172° 30′, and 174° 40′, thus indicating a maximum variation equal to 2° 51′ in a line not more than 60 yards in length.

Ex. 2.—In a heading driven in a vein of coal 4 feet thick, and into and through a piece of faulty ground, consisting mainly of a mixture of rock and cliff, a line of about 60 yards in length was ranged out as before, and the instrument fixed first at that end of the line away from the "fault," and the light observed and read at the other end of the line within the faulty ground; seven other positions were then fixed upon in correct alignment in succession towards the other end, and the readings taken at each, and the result was the following series, viz., 36° 24′ 36° 20′, 37° 50′, 38° 15′, 39° 40′, 39° 10′, 38° 10′, and 37° 0′, in this case indicating a maximum variation equal to 3° 20′.

The line of the "fault" crossing the alignment of the several positions was an acute angle, and the sixth reading was about in the line of its crossing, and the seventh and eighth readings were within the fault.

By referring to the several readings it will be observed that there was an increasing divergence in the same direction (to the right) in approaching the fault, and that after entering the fault there was a sudden twist back again in the contrary direction.

Ex. 3.—A series of magnetic bearings was taken in an engine plane underground, which was driven quite straight from end to end, and the bearings were taken previously to the setting up of the ordinary fixtures of an engine plane, which usually interfere with surveying operations prejudicially; and over a length of about 330 yards the following readings were accurately observed, viz., 346° 55′, 345° 0′, 346° 42′, 346° 15′, 345° 0′, 346° 30′, 346° 9′, 345° 48′, and 347° 3′, thus showing a maximum difference equal to 2° 3′.

Repeated trials on carefully ranged out surface lines do not indicate the prevalence of so great a variation of magnetic readings as underground lines, but even these show frequently a marked variation. The following examples are given as evidence of this:

Ex. 4.—On a surface line of about thirty chains in length the instrument was set up five times in correct alignment, and observations taken, and in this particular example the readings at each position corresponded precisely with all the others.

From one end of the previous line, and almost at right-angles with it, another line of about twenty.four chains was ranged out in the same manner as before, and the following series of readings taken:

Ex. 5.—54° 58′, 54° 51′, 54° 44′ and 54° 58′; these therefore almost indicate a much less variation than in the lines underground.

Ex. 6.—In a long carefully ranged base line of a surface survey of considerable extent several observations were taken as at other times, and the following were among the readings taken down, viz.: 114° 41′, 114° 41′, 115° 7′, 115° 21′, showing in these a maximum variation of 40′. This variation, although it does not look so formidable as some of the previous ones given, yet, when analyzed, it represents something serious; for if viewed in reference to the length of that section of the line, at the extremities of which the instrument was set up and the readings taken—in one case 40 chains, and in another 26.45 chains—we shall find that in the former case the *twist of position* due to the variation (and consequently the error that might have been thus imported into the work), is equal to 46.5 links, and in the other case it is equal to 30.7 links; and this is a consequence scarcely to be neglected or overlooked.

The foregoing examples, confirmed by many other observations made from time to time, plainly indicate that the magnetic needle does not—even when used on the earth's surface—maintain generally an accurate parallelism, and that when used in underground operations the variations are generally much more marked.

This subject has, of course, a primary

bearing upon the use of the magnetic needle in surveying operations; but it has often occurred to me that this effect of the ceaseless operation of magnetic forces may not be, and most probably is not, the sole and only consequence of manifestation to us.

What the intrinsic change really is which a piece of steel undergoes in the process of being magnetized, and converted into a magnetic needle, I have never been able to understand to my own satisfaction; but my observations lead me to suppose that whatever the *internal* change may be upon the steel, it results *externally* in imparting to the needle the power to *conform to the direction* of the current of magnetic force passing around it at the moment, and in the position in which it is being used.

I have often observed on different occasions that the needle seems to be more deflected from its true parallelism when used in close proximity to faulty and disturbed ground, and also when used in headings passing through such varying ground as is met with in what is technically known as "crossing the measures," than in ground of a more uniform nature, whether it be an ironstone mine or a coal mine; and the conclusion I arrive at in view of these experiences and circumstances is, that the needle deflections represent the deflections of the passing current of magnetism in the surrounding strata, and that these deflections of the current are again the result of the varying powers of conduction possessed by the varying strata of the earth; that, in fact, as water turns aside from the more confined parts of its channel to that which affords it the freest passage, so does the magnetic current get slightly deflected, first to one side, and then to the other, in its passage through the strata, the best conductor conveying the greater quantity; and when this superior conductor comes to an abrupt end, or becomes distorted or disturbed, either from a "fault," or from some other cause, the current becomes more or less deflected, and the magnetic needle used in close proximity to such a position, or locality, would also in its turn become deflected in sympathy with the current.

But I conceive that there is a great probability that this same subtle power frequently operates to the causing of other consequences, which are often not a little perplexing to account for, and to understand.

In that state of the weather when the atmosphere is highly charged with electricity, and heavy storms of rain are frequent, we often experience the springing up of a sudden wind, which, leading in the van, as it were, as well as bringing up the rear of the disturbed elements, blows furiously for a while until the rain has ceased, when the wind again gradually subsides into a perfect calm. To my mind the theory that winds are caused by the rarefaction of the atmosphere in certain localities, to which the air rushes to restore the equilibrium—thus causing winds—utterly fails to afford a sufficient and satisfactory explanation of the occurrence of these suddenly springing up and as suddenly subsiding winds, carrying, as they seem to do, a furious storm of rain, or hail, or snow in their bosom.

But whatever may be the intrinsic nature of the force put into operation, whether electricity striking out abnormally (if such an expression may be permitted) in a deflected line or otherwise, it is certain that the *vis viva* of the power thus set in motion represents an enormous aggregate of force, as the destruction sometimes wrought by a small portion of it sufficiently attests.

Disasters, sudden and startling, sometimes occur in collieries from the explosion of gas; and the only explanation frequently possible is, that a sudden outburst of gas has occurred and overpowered the ventilation, and that from a defective lamp, or from an unprotected light, the gas exploded; and we not unfrequently find the sudden outburst of gas explained and accounted for by saying *that a "fall of roof"* took place. Now I am strongly of opinion that where these two things are found to have occurred together, they are not necessarily, nor obviously, cause and effect in the order named, but that, much more probably, if they are not two effects of the same cause, the fall of roof is a consequence of the explosion.

When a vein of coal has been extracted from its position in the strata over a considerable area, the roof, or the floor, or both, will be sure, sooner or

later, depending upon their natural and also their relative strength, to show a tendency to close up the space from which the vein of coal has been extracted; if the strata in which the coal lies is of a friable nature, and readily breaks up, the large interstices resulting from its closing up the space formerly occupied by the coal will necessarily be much more ramified throughout the broken strata, but will not form one or two large chambers; if, on the other hand, the strata is of a more tenacious nature, and will bear a very considerable subsidence or elevation before it will break up, then a chamber more or less large, either in the back of the subsidence or beneath the upheaval, or both, will necessarily be the result.

These ramifying intervening spaces as in the first case, or the more extensive chambers as in the second case, will not be in vacuum, but will become filled with the air or gas, or a mixture of both, so fast as they are formed; if the strata give off carburetted hydrogen gas, then it may be taken for certain that an explosive mixture will very soon, by reason of the operation of the law of diffusion of gases, occupy the whole of the spaces and chambers so formed.

Let us now assume the occurrence of quickened activity in the earth-currents in our latitudes as are so frequently, though more forcibly, experienced in some other parts of the world (and which, when they are atmospheric, *we* have such sensible and frequent experience of), and we shall not be assuming too much if we credit those earth-currents with a very largely increased *vis viva* under such circumstances; let, then, such chambers as are mentioned above, and filled with an explosive mixture of gas, lie in the path of such earth-currents, and their *vis viva* will immediately tell upon a body so imponderable, and such an impulse would be imparted to it as would immediately drive a considerable portion of it through the joints of the ground communicating with the coal workings, and if a naked light or a defective lamp should be within its reach an explosion would be certain to ensue; and once a portion of it became ignited, the explosion would extend to wherever the train of the gas in the requisite mixed proportions extended, even to the partially emptied chambers of the roof or floor; and where such happens the strongest roof must give way and be blown down, seeing that the expansive energy of such gas immediately after explosion is about five atmospheres, or 75 lbs. per square inch. And hence I consider it much more probable that the "fall of roof" is the result of the explosion instead of its being an antecedent consequence of it, and contributing in that sense to bring it about.

A friable roof and floor may, also, in this view, from the fact of its more readily breaking up, and thus preventing the accumulation of so large a lodgment of gas in a single chamber, and also by facilitating the more continuous drainage of the gas into the passing air of the mines, render the colliery far less subject to sudden outbursts of explosive gas than a mine with a much stronger and more tenacious surrounding strata would be; and thus, on the whole, the former would be more safe from that class of accident than the latter.

I cannot deny of course that some of the opinions I have expressed here, and some of the conclusions I have drawn from them, may possibly be characterized as being insufficiently supported by my premises; the existence, however, of such magnetic variations as I have here demonstrated, and the known fact of the existence of those powerful earth-currents that make their presence and power felt so forcibly in some other parts of the world; and also remembering those atmospheric disturbances which are so universally felt at times in all parts of the world—these appear to me to justify such a train of reasoning as that I have here entered into; and if what I have here written should lead to investigations by abler hands than mine, from which good may ensue, and our knowledge of these things become more extended, I shall be as much gratified as any one else can be.

In an interesting paper lately read at a meeting of the Royal Society, on "Experimental Researches on the Temperature of the Head," Dr. Lambard showed that mental activity will at once raise the temperature of the head, and that merely to excite the attention has the same effect in a less degree.

CLEOPATRA'S NEEDLE AND ITS WORKMEN.

From "The Builder."

We have had the opportunity of carefully inspecting the now familiar Cleopatra's Needle. It has been exposed partially to public view, and a little at least can be readily seen from the Embankment. We call attention to it now, and while it is in its present *bonâ-fide* state, as it is while in that state that such a monument is really and truly interesting to the lover of past art and methods of workmanship. So much indeed,—may we not say everything?—round and about us of our own antiquities has changed and been modernized, that a glance,—as here,—at a genuine "antiquity," in its rough and time-worn state, is quite a novelty,—a something really strange to see, and leaving an impression not to be got at in any other way. The preparatory work, it may be mentioned, of providing a pedestal for it to stand on is rapidly progressing; and it is earnestly to be hoped that this too elaborate pedestal will not dwarf, and make quite secondary, the monolith itself. We here propose to make note of it as it now is, and while it tells so simply its own story, and to call attention to the workman's part in the granite cutting and carving of it, and which, to say truth, needs no added work to make it attractive.

So many descriptions and accounts of this "Needle" have been already given that it must needs be familiar to most, but there are yet one or two things connected with it which have been hardly noticed; but they are vital elements in the matter notwithstanding. A word or two, then, may at the present juncture prove useful. We are told in an authoritative book on Egyptian history and antiquities, that of all works of Egyptian art in simplicity of form—we ask note of this—colossal size, and unity and beauty of sculptured decoration, none can be put in comparison with the obelisks. The Cæsars of Rome vied with the Pharaohs of Egypt in their admiration of the obelisks, but it is not said that these same obelisks were put up in the places where they were found, because they were pretty to look at, or as attractive monuments; they were, indeed, and simply, pieces of the temple furniture, just as much so as any item of church furniture is a thing of use and necessity in a church of to-day. Obelisks never stood alone and isolated as this one on the Thames Embankment is to stand, but always in pairs, and immediately in front of some building or pylon; so that in approaching them, and getting sight of them, they were seen detailed against the huge mass of walling near which they stood, and were thus seen at their very best, their long shadows being all but a part of them.

The use and origin of the obelisk is yet as debateable as ever, and why these were placed at the entrance of the great temples, and always in pairs, is not apparent, and whether or no any pause or ceremony took place on the occasion of the long procession when passing between them into the Temple is not known, and can be only conjectured. All that we do know is, and of this we may feel quite sure, that they were not cut out from the quarry, and brought to their places, at such a vast cost of labor, for the mere sake of putting a something in the places where they stood, but that they had a peculiar and highly significant meaning, and were, indeed, essential parts of the Temple apparatus, whatever that might have been. It may be that, could we be quite sure of the hieroglyphic reading, this would be explained. Objects so conspicuous and so striking must need have been highly symbolical in purport, and must have been as open books to be read in the passing by them. This absence of a building, of which the obelisk formed a part, and the fact of the ever-present but mysterious writing on it, would startle the old Egyptian builders and workmen not a little, could they but return for a brief moment, to look at their work on our river Embankment.

But our object at present is not to go into the history, and even uses, of the obelisk, but to make note of its artistic

character, and of the cutting of the hieroglyphics on its huge surface. We have examined this with some attention, and would recommend the study of it to our stone-carvers. The actual material out of which this monolith is cut is hard granite, and right good tools and skillful hands only could have made impression on it. This granite-cutting is remarkable in many ways. It is not simply the carving out of the hard and intractable substance the forms we see, but the indications of manner which are to be noted in the doing of it. Large, and apparently rough, as the granite-cutting is, there is the constant presence of the artist workman to be seen in it. The surfaces are not all of a uniformly dull flatness, as such work would now be made, and as it is done when "lettering" is cut out of stone; but a thorough knowledge of the form and even life of the object represented is here, when such object admits of it. We would here ask the attention of those who have to do with such specimens of the workmanship of so long a bygone day to note this, so that no attempt whatever may be made at "re-cutting," or mending, or "restoring," as it would be called, of the work, or even repolishing it. If this be done, all the antique life of work goes. We hear that this is under consideration, but if so, before it is done, may we suggest casts of the hieroglyphics, and thus that, at least, a true record be preserved of them.

These hieroglyphics should be studied while the obelisk is where it now is, on a level with the eye. One thing, by the way, little as we know about the matter, was intended by those who erected obelisks, and that was that they should be as ever-open books, to be readily and easily read, they always standing on a low block of granite, so as to admit of this. The letters were close to the eye as could be, and even when near the top of the monolith were so large, and so deeply incised, that they could be readily read from top to bottom. Indeed, the longer this magnificent granite cutting is looked at, the more do you wonder at it, and at the skill with which it is done. In the clear sunlight of Egypt these hieroglyphs show themselves with an almost startling precision and distinctness. The old Roman was justly proud of his lettering on his buildings, and right well he did it, but it quite pales before such works as this, where the *forms* even admit of vitality in the rendering of them. Again, then, may we express a hope that they will not be tampered with, but left as the antique carvers cut them, and no attempt made to "polish" or recut them, or, indeed, in any other way to destroy or mar their individuality and antique expression.

We are here looking at this huge monolith as a specimen of the work that in its time was done in Egypt, and we cannot but wonder at the power of such work, when contrasted with what is now possible. Compare the mechanical appliances *then* and *now*, and well may we wonder at the skill and patience of the old Egyptian quarrymen and granite-cutters, who managed to subdue even this huge mass, and to cut it out of its natural bed, and to afterwards move it into its place. Nothing, indeed, would seem to have been too huge for the Egyptian workmen; blocks, however large and weighty, were quarried and moved long distances, and then set up with an ease and skill which might appal even our mechanical and steam-aided powers. Indeed, we hardly know which to wonder at most, the power displayed by the old workmen in the cutting out and the moving of such huge masses of so hard and solid material, or at the artistic skill and feeling afterward displayed in the "ornamenting" of them. We have much to learn even in these advanced days, and but few able to doubt it; but if any do so, why here is a proof in point, and he who runs may here read.

We do not intend just now to say a word on the pedestal, but would remind lovers of genuine antiquity that those who designed this monolith never dreamed of anything of the sort threatened!

It is impossible to make note, however slightly, of this really magnificent example of the skill and artistic power of the working artists of Egypt without an earnest hope that no attempt will be made to add to it anything that can be avoided.

It may here be of interest to mention that an Arab writer, in the twelfth century, notes that the obelisks had even in his day "copper caps" on their tops;

but these without doubt, he hints, were after-additions by those who had conquered the country. Our object now should, as we think, be to preserve this monument as an *Egyptian* antique, and as one purely and solely Egyptian, and thus to see it, as they of Egypt of old saw it, in all its simplicity and harmony of outline and strength of granite cutting. An obelisk is in itself so simple an object that it is impossible to add to it without, at the same time, taking away from it. Like a Stonehenge block, it can not be added to without injury.

HOW IT IS TO BE ERECTED.

The cylinder and its contents having been floated some three or four weeks ago over the temporary gridiron made to receive it on the up or Westminster side of the Adelphi Stairs, was, before being allowed to permanently rest on the gridiron, canted over on one side by the simple expedient of shifting the ballast. As canted over, the bottom of the vessel faced the Victoria Embankment, while the upper or deck side faced the Surrey shore. The vessel was canted over in order that that side of the monolith which is least "weathered," or, in other words, which retains the most sharply-cut hieroglyphics, should be parallel with and face the Embankment roadway. The side which will face the river is the most weathered of all, the remaining two sides, which will be at right angles to the Embankment roadway, being not so much worn. The vessel having been canted over, the first thing to be done was to begin pulling it to pieces. Nearly all the iron plates were removed, the ribs remaining intact, and the obelisk, wedged up from the gridiron, remained submerged at high tide. During low tide the obelisk, which has its point or pyramidion in the direction of Waterloo Bridge, has been slowly moved forward by means of hydraulic jacks, until, at the time of writing, the obelisk has emerged, point foremost, a considerable distance out of its iron shell, the apex nearly touching the stairs on the up or Westminster side. The next operation will be to raise the obelisk bodily to a height sufficient to clear, and to allow of its being traversed partially over, the landing between the two flights of stairs. When the obelisk has been centrally placed over this landing, it will be again raised to a height just sufficient to clear the two masses of granite (part of the Embankment structure) which will flank the obelisk when erected, and which masses it is proposed to surmount with sphinxes. Having attained this height, it will be moved laterally towards the Embankment roadway until it lies across the center of each of the flanking masses or pedestals of granite referred to. The obelisk will be moved in all cases by means of hydraulic jacks, and carefully "packed" as the work proceeds, so as to prevent undue strains upon it. The obelisk having been got into the position indicated, *i.e.*, lying horizontally across the spot upon which it will stand, will be cased in its central portion with a wrought-iron jacket, about twenty feet long, and riveted at the angles. This jacket will be made to fit pretty tightly by means of wedges of wood, and in order to prevent the stone from slipping out of this jacket a wrought-iron strap will be carried round from side to side under the foot of the obelisk. This jacket, which will weigh about 16 tons (making, with the obelisk, which weighs about 186 tons, a total of about 200 tons), will be fitted with strong projections or trunnions on the two sides facing the Embankment roadway and the river respectively, and these trunnions will rest upon two specially-made wrought-iron girders lying parallel with the obelisk itself. Each of these girders will be raised at each end by means of a hydraulic jack, and will work in and be guided by the recesses left in each of the four main uprights of the specially-designed scaffolding which will then have to be erected. Roughly speaking, these four uprights will form the corner boundaries of an oblong space 17 feet by 8 feet 6 inches, the two longer sides being parallel with the obelisk and spanned by the girders before mentioned, and the obelisk projecting for about a third of its length beyond each of the shorter sides of the imaginary oblong described by the four uprights. These uprights will be about fifty feet high, and will each consist of six "sticks" of timber, twelve inches square, arranged and bolted together three and three, parallel with the obelisk, with a space nineteen inches wide between each six for the ends of the girders to work in.

These uprights will, of course, be thoroughly braced together and stayed and strengthed by raking struts, &c. Each end of each girder will be simultaneously raised and "packed," until the girders, supporting the obelisk in a horizontal position by means of the trunnions of the iron jacket before described, shall have attained a sufficient height to allow of the whole mass being swung round on its trunnions, so that its base shall be but a short distance higher than the pedestal prepared for it, when, all being right, it will be gently lowered to its position. The pedestal, we may say, will rest on a foundation of Portland cement concrete, carried down to a depth of forty feet to the London clay. This part of the work has been executed by the Metropolitan Board of Works, for and at the cost of Mr. Dixon. The pedestal itself will be of hard bricks, set in Portland cement, and faced with blocks of gray granite (the same as that used for the Embankment wall) of considerable size. Of this pedestal a portion has been already erected, but the remainder will have to be built up after the obelisk has been raised, by the means described, above the highest course of the pedestal. A shallow groove will be provided on the top, in order to allow of the removal of the wrought-iron strap, already mentioned. Although the four corners of the lower part of the obelisk are very much abraded, there still remain about twenty-four superficial feet of flat surface at the bottom, and this extent of bearing surface will, it is believed, be fully sufficient to insure stability.

We believe that nothing is definitely decided as to the proposed sphinxes; but we may note that, in the "Visitor's Book," a gentleman has put on record the substance of a conversation he had with the late Mr. Joseph Bonomi, who expressed the opinion that, if sphinxes are to flank the obelisk, they should be of a date coeval with that of the obelisk itself. Mr. Bonomi only knew of two such sphinxes—one in the National Collection at Paris, and another in the Duke of Northumberland's collection at Alnwick—and he suggested that one of these should be adopted as the model of those which it is proposed to place in juxtaposition with the obelisk.

The work of getting the obelisk into position must necessarily proceed slowly. It is hoped, however, that the work will be safely effected by the end of August.

PROBLEM FOR ROLLING STOCK AND RAILWAY BUILDERS.

From "Iron."

Our English railway system is, beyond question, the most complete that exists. Nowhere else are such facilities enjoyed for reaching any desired point, and in the matter of high speed we lead by great lengths. Still we are far off perfection, and, indeed, in many minor respects our Continental and transatlantic neighbors excel us. One of these is the attention paid to the comfort of passengers; another, the better training in courteous bearing of officials; and others will readily suggest themselves to any who have had opportunities of instituting comparisons. One drawback to railway journeys in England is the swinging from side to side of the carriages. This is not a defect peculiar to us. It is no more guarded against across the Channel or in the United States than here. But in England we suffer more from the annoyance, because express riding is popular; and the measure of carriage oscillation much depends on the velocity of travel. The swinging and jerking incident to a ride of a hundred miles or so in an express train enervate and distress travelers, and, whatever the demands upon them, effectually bar the weak or invalid from so voyaging. The drawbacks are so manifest as to make it not a little remarkable that builders of permanent way and of rolling stock have not long since devised means to remedy them. The "Bogie" principle was evolved to meet the difficulty, and has contributed fairly to that end, we believe; but even that—and it can only be re-

garded as much less than what may be accomplished—has not been taken kindly to by railway corporations. The Midland is the only large company which has even partially adopted it. Probably the lack of remedy is traceable to absence of demand. We grumble at inconveniences long before we clamor, and it is only clamor that can wring concessions from railway owners, whom we are pleased to regard as the servants of the public, but who treat the public as farmers do their turnips—make as much out of them as they can with the least outlay. *Sotto voce* protest has now, however, ended, and agitation has begun. It is a singular fact that during the whole fifty years since railways were first introduced there has been no improvement in the wheel and axle arrangement, and the rigid fixture of the wheels now is just the same as Mr. George Stephenson adopted, and, indeed, found adopted when as a boy he saw them at work in the collieries of Durham. Two wheels are practically welded to a bar of iron, and neither of them can move without the other, so that in passing over a curved line of railway which has two rails of different lengths one of them must travel over a longer space than the other. In order to modify the natural action of these opposing conditions, the outer, or longer rail, is "banked up," and thus the perpendicular line of the load is changed, and the "grind" is produced by the flange rubbing against the rail; and it is owing to this action that so many train accidents happen of vehicles leaving the line. One of the wheels must "skid" more or less, and friction is thereby very much increased, the "wear and tear" of both the wheels and the permanent way is largely augmented, and so is the danger. An interesting correspondence is now going forward in *The Times* touching this matter. It was initiated by Mr. James Howard, who having, during two journeys to the Paris Exhibition, been keenly annoyed, was prompted to ask, "Have railway companies in England kept pace with the general advance?" Replying to his own query, he says: "If this question were to be answered from the experience gained upon the South-Eastern, and London, Chatham and Dover lines, it would, I think, have to be answered in the negative: on the contrary, if answered from experience of the Midland Railway—upon which I reside, and upon which many improvements have been adopted—it would, unquestionably, be answered in the affirmative. About a month ago I came to Paris, and chose the London, Chatham and Dover line, but owing to the oscillation of the carriage being so violent and alarming to myself and fellow passengers, I determined to try the South-Eastern route, and left London by the 9.25 p.m. train for Folkestone. Bad as was the former line, portions of the South-Eastern if anything were worse; the oscillation was so violent just before reaching Sevenoaks that, upon the train pulling up at that station, I left my carriage to speak to the guard. Upon saying to him there would be accident before long unless some improvements were made in the road we had just passed over, he remarked that for such high speeds this portion was bad. I do not want to endanger the lives of such valuable public servants as Colonel Tyler or Colonel Rich, but am persuaded if either were to take a trip on these two lines at express speed he would come to the conclusion that improvements were imperatively called for. I hope to see, at no distant date, engines and carriages upon the 'Bogie' principle universally adopted, as well as simultaneous, automatic brakes; they work admirably on the Midland. Time of course must be allowed for the wearing out or conversion of the existing rolling stock, but in respect of permanent ways, surely railway companies are bound by every moral consideration to maintain them in the highest possible condition; to alarm their passengers in the way I have described through failure so to maintain them is, to say the least, unpardonable. To feel that your carriage, being propelled at forty or fifty miles an hour, cannot keep the rails with so much swaying and bumping is a trial even those with the strongest nerves do not care to have repeated." Mr. Francis W. Dean, tutor in engineering at Harvard University, U. S. A., has also taken part in the correspondence. He says he has noticed on nearly every railway he has traveled on in Great Britain the same defects of which Mr. Howard makes complaint and endorses what he says touching the value

of the "Bogie" system as a remedy. This system, he adds, has further to recommend it the fact that it prevents the grinding of the flanges on the rails. In support of the latter proposition he writes :

"Although I have had an opinion upon this matter for an indefinite time, at York, the other evening, I became convinced that the amount of the grinding is not over-estimated by advocates of the Bogie system. While waiting at the station in that place, I heard squeaking between the flanges and 'metals,' which far exceeded anything that I had ever anticipated. The locomotives were noble specimens, and belonged chiefly, if not wholly, to the North-Eastern Company. As the Australian commissioner, Mr. Higinbotham, in his report of the railways of the world, has substantially remarked, such locomotives and carriages would hardly keep on the rails on less perfectly permanent ways than those in Great Britain. I may remark that I have traveled in both the Bogie and common carriages of the Midland Company, and found the difference very striking." The gravity of the defect animadverted on is palpable and the necessity for removing it obvious : and there are few save railroad proprietors who will not agree that should the adoption of the "Bogie," or any other remedy, ensue from the correspondence, a service will have been done the public by Mr. Howard and those who have with him participated in it.

STEEL PLATES AND RIVETED JOINTS.

From "Engineering."

A CIRCUMSTANCE connected with the greater ductility of soft steel compared with that of iron plates, which appears to us to require consideration, is the effect of this greater ductility upon the crippling strength of the plate, and consequently upon the proper proportions of the riveted joint. The softer and more ductile the plates the more liable is the material at that side of the hole that bears the stress to be crushed or crippled by the rivet bearing against it.

With iron plates and iron rivets, in order that the tearing, shearing, and bearing resistances may be theoretically equal in single riveted lap joints, if we take the thickness of the plate as unity, and assume the tearing stress to be equally distributed over the section of the plate between the holes, and the plate to receive no damage by punching the thickness of the plate, mean diameter of hole and pitch of rivets will be represented by the numbers 1, 2.6, and 7.6, the efficiency of the joint or the ratio of the strength of the joint to that of the solid plate being 0.66. As the diameter of the rivet holes in $\frac{1}{2}$ inch plates seldom in practice exceeds twice the thickness, and the pitch $4\frac{1}{4}$ times the thickness of the plate, it is evident there is an excess of bearing strength over both the tearing and shearing strength in $\frac{1}{2}$ inch plates with the usual proportions of joint, and this excess increases with the thickness of the plates, taking the diameter and pitch of rivets generally used.

With double-riveted lap joints taking the thickness of the plate as unity, we should have the thickness of plate, diameter of hole, and pitch of rivet represented by 1, 2.6, and 12.75. In practice, the pitch in $\frac{1}{2}$ inch plates double riveted seldom exceeds seven times the thickness, and three and a half times the thickness in 1 inch plates, so that the excess of the bearing over the tearing strength is even greater than in single riveting, the excess over the shearing strength remaining the same.

In reducing the thickness of plate when substituting steel for iron plates by the amount allowed by the excess of tenacity of the former over that of the latter, or, say, by 25 per cent. if we retain the same pitch and diameter of rivets, we shall maintain the same proportion of tensile and shearing strength in the plates and rivets, neglecting, for the present, in the case of lap joints the increase in the proportion of strength due to the stress being less out of line at

the overlap of the thinner plates of steel. The bearing surface of the plate will, however, be reduced by 25 per cent. If the resistance of soft steel to crippling were greater than that of iron, in the same proportion that the tenacity is greater, the reduction of bearing surface would be compensated for by the greater resistance to crippling. As, however, the ductility of soft steel is considerably greater than that of ordinary iron plates, it is extremely probable that the resistance to crushing is less. The resistance to crippling no doubt varies widely in different qualities of iron plate, but comparatively little is known of this resistance in iron and still less of that in steel plates. From the results of the few experiments that have been made with a view to ascertain its value for iron it is usually taken at twice the tensile strength of ordinary boiler plates.

If we take the tenacity of steel as being one-third greater than that of iron, which allows a reduction in thickness of 25 per cent. only, and assume the resistance to crushing as being 25 per cent. less, in order to compare the proportions of joint for equal tearing, shearing, and bearing resistance, we shall have, using the same mode of comparison as above, 1, 2, and 4.4 representing the thickness of plate, diameter and pitch of rivets for single-riveted lap joints in steel, and 1, 2, and 6.8 for double riveting, giving an efficiency of .54 and .70 respectively. These theoretical proportions of joints are much nearer what is used in practice than is the case with iron plates. In replacing $\frac{1}{2}$-inch iron plates with $\frac{3}{8}$-inch steel plates, and using $\frac{3}{4}$-inch rivets at $1\frac{5}{8}$-inch centres for single and $2\frac{1}{2}$-inch centres for double riveting, we shall have a joint with the tearing, shearing, and bearing resistances all equal. In replacing a 1-inch iron plate by a $\frac{3}{4}$-inch steel plate, we should require $1\frac{1}{2}$-inch iron rivets at $3\frac{1}{4}$ inch centres for single and at 5-inch centres for double riveting in order to have a theoretically proportioned joint, and by using $1\frac{1}{4}$-inch rivets at $2\frac{1}{2}$-inch and $3\frac{1}{2}$-inch centres respectively for single and double riveting, it is evident we shall have an excess of bearing resistance over that for tearing and shearing.

In the report of Lloyd's Registry Committee on steel for boiler making it is stated that in consequence of the crippling of the material behind the rivets in some experiments, it appears that a greater proportion of bearing surface is required with steel than with iron. Unfortunately the dimensions of the joint that thus failed are not given.

There are two ways of bringing up the bearing surface, (1) by increasing the diameter of the rivets, and (2) by increasing the number of rivets. By increasing the diameter of rivets and maintaining the same pitch, we diminish the efficiency of the joint, and if we attempt to increase the pitch in order to maintain this efficiency, we neutralize the very advantage sought in increasing the diameter of rivets. It must not, however, be forgotten that by increasing the diameter of rivets without altering the pitch, we may increase the proportion of bearing surface by a much greater amount than we reduce the proportion of tearing section. For instance, by altering 1-inch rivets at $3\frac{1}{2}$-inch centres to $1\frac{1}{2}$-inch rivets, we increase the bearing surface by 50 per cent. whilst we reduce the shearing section 20 per cent. only. In all cases it must be a question whether the increased bearing strength obtained by increasing the diameter of rivets is wisely bought at the expense of the efficiency of the joint. Whether we maintain the same pitch or not, we give a preponderating shearing strength to the rivets, by increasing their diameter beyond the usual practice for iron plates.

In seeking to obtain additional bearing surface by increasing the number of rivets in the same line and reducing their diameter, we reduce the tearing strength to the same extent as by increasing the diameter and maintaining the number of rivets. In this case we injure the plate more by punching, but the stress will be more evenly distributed over the plate, and we get a joint that is more easily made and kept tight if the rivets are not made unduly small. Here again the proportion of tearing section is not so rapidly reduced as that of the bearing surface is increased. Suppose we replace 1-inch rivet holes at $3\frac{1}{2}$-inch centres by $\frac{3}{4}$-inch rivets at $1\frac{3}{4}$-inch centres, the bearing surface will be increased 50 per cent. and the tearing section diminished 20 per cent., the shearing section being increased about 12 per cent.; or by using

$\frac{7}{8}$-inch holes at $2\frac{5}{8}$-inch centres, the bearing surface will be increased 16.6 per cent., whilst the tearing section will be reduced 6.6 per cent. only. When additional bearing surface is actually required, it is best obtained by making an additional row of rivets in the joint.

The carrying out of the recommendation to increase the diameter of rivets when substituting steel for iron plates may easily be pushed too far, and counteract some of the benefit we should expect to derive from the superior ductility of steel. If all rivet holes were drilled fair with the plates in position and close together, and if every hole were filled by its rivet to make a perfect job, in which each rivet takes its share of the stress distributed over the length of the joint, it would even in this case be scarcely advisable to proportion the joint so as to bring the crippling strength up to the tearing strength of the plate, for it is much better that the holes should elongate by crippling under severe stress, such as that caused by unequal and sudden contraction, and give warning by leakage, which might not require the renewal of the plates to render the boiler serviceable, than that attention should be drawn to the presence of the straining by the fracture of the plate from hole to hole, which is always a serious if not dangerous defect requiring partial or complete renewal of the plate, and which may occur without giving warning, through the crippling strength of the plate being kept too high.

When we increase the size of the rivets, we increase the bearing surface only directly as the diameter of the rivets, but the shearing strength as the square of the diameter. We should therefore increase the pitch in proportion to the square of the diameter, assuming of course that we are dealing with a joint well preportioned in the first instance, in which the plates between the holes should have a margin of tensile strength over the shearing strength of the rivets, since the plates are liable to become reduced in strength by punching and wasting, whereas the portion of the rivet between heads being protected does not become so much reduced. When the joint is not so proportioned, the less are we justified in still further giving a preponderance of strength to the rivet already too large. The greater the pitch of rivets the more is the strain concentrated at the sides of the holes, and consequently the greater is the tendency of the plate to be broken piecemeal and the breaking strength to be thereby reduced. Hence increasing the size of the rivets and attempting to maintain the efficiency of the joint is tantamount to increasing the brittleness of the plate, and by injudiciously proportioning a joint we may to some extent at least neutralize the advantages expected to be gained by annealing and using a ductile material.

One very important point should not be lost sight of in proportioning a joint, and this is that it is far more difficult to make a good repair job with large rivets than with small ones, especially in inaccessible situations, and where the pitch is increased to maintain the section between rivet holes when using large rivets, the difficulty of making tight repairs is still further increased.

Perfect tightness in a joint without theoretical correctness of proportion is of far more importance than correct proportions which may fail to secure perfect tightness. One boiler-maker may have appliances which will enable his men to make perfectly tight and sound work with rivets of unusually large diameter and pitch, and with which another maker would fail to make satisfactory work. The cases of boilers that have given way, and of expensive repairs that have been required through the rivets being too small, are very rare in comparison with the disasters that have occurred, and the expenses that have been incurred, through wasting of plates in consequence of leaky joints. No doubt it is advisable to keep up the ultimate breaking strength of the joint by increasing the diameter and pitch of rivet, but it is absurd to do it to such a degree as to risk making the plate weaker in the solid than in the joint, which it will inevitably become in time should the joint leak. If the wasting of steel plates occasioned by leakage took place only at the same rate as that of iron plates, the reduction in thickness with the former would render them less durable. But there is reason to believe that the wasting will be more rapid with steel in certain situations, hence the importance we attach to having perfectly

tight joints, lest the material should be blamed, instead of the design and workmanship, in the case of a boiler wearing out rapidly. The crippling strength of a ductile steel plate in front of the rivet may be considerably increased by increasing the lap or distance between the edge of the plate and center of rivets. With lap joints the practical objection to this is that beyond a certain limit, usually taken at one and a half times the diameter of rivet, the difficulty of making a joint tight by caulking or "fullering" increases with the amount of lap.

But in butt joints this objection is got over by increasing the lap of the plates only whilst retaining the usual amount of lap between the rivets and the caulking edges of the strips or welts. In double-riveted lap joints a considerable advantage in strength will be gained by increasing the distance between the lines of rivets in steel plates beyond the usual practice for iron plates, especially in zig-zag riveting.

STRUCTURES IN AN EARTHQUAKE COUNTRY.

By JOHN PERRY AND W. E. AYRTON, Professors in the Imperial College of Engineering, Tokio, Japan.

From "The Architect."

When working at our paper on "A Neglected Principle that may be Employed in Earthquake Measurements," read before the Asiatic Society of Japan, May 23, 1877, we were led to consider how the effect produced by an earthquake on a structure is influenced by the time of vibration of the structure.

It follows from that principle that if a number of quickly vibrating bodies form part of the same structure, they all vibrate in much the same way; that is, the periods of their swings are all approximately equal to one another and equal to the periods of the earthquake; and although they differ in the amount of their motions these amounts and their differences are all exceedingly small; whereas if one or more of the parts of the structure are only capable of vibrating slowly, the periods of vibration of the different parts vary very much, the amounts of the motions are all comparatively great, and their differences are all relatively considerable. If, however, there is a sufficiently great viscous resistance to motion of such slowly vibrating parts, these parts will be found during an earthquake to behave much as if their natural periods of vibration were quick. Supposing the foundation of a structure to vibrate with the earth which encloses it, we see that a slowly vibrating structure which is fastened to these foundations is during an earthquake subjected to stresses which may be excessively great and of a very complicated kind, whereas a quickly vibrating structure is subjected to stresses which may be said to be determinate, and which are comparatively small. It is not here necessary to consider whether, as all the motions of a quickly vibrating body must be small, such a structure will be more comfortable to live in, because it is doubtful whether the annoyance produced by rapidity of shock would not more than counterbalance the annoyance of great but smooth motions. It is only safety we are here considering, and in this respect there can be no doubt of the superiority of rigid structures, or of structures having a sufficiently great viscous resistance to motion. We have made some calculations of the times of vibration of ordinary structures, such as well-built houses of stone and brick, chimneys, lighthouses, &c., and from these we see that the periods are all much less than what we judge from our experience is the ordinary period of vibration of earthquakes in Japan. Even two-storied houses built of wood if framed in the best way have quick times of vibration; such structures are, therefore, it seems to us, well capable of resisting the ordinary Japanese earthquake shock. As, however, we have not yet experienced the effects of a destructive earthquake, and as we presume that one of

the most important ways in which it may differ from ordinary earthquakes is in the suddenness of motion, or change of motion, it cannot be said that any ordinary structure has a quicker period of vibration than a destructive earthquake; consequently, if it be granted that stability depends on the structure having a quicker period of vibration than that of the earthquake, the stability of a building will be only relative; we can, of course, be sure that by making the walls of a building thicker and its height less that we add to its safety, but however far we may go in this direction we cannot be certain but that after all the earthquake period may be less than that of our building.

We must, therefore, content ourselves with saying that a slowly vibrating structure will probably get broken in its connections with the foundations if these be rigidly fixed to the ground, consequently (and we here oppose the practice of many architects and engineers) putting a heavy top to a lighthouse, the chimney of a factory, or other high building, must certainly take from its stability. And although the times of vibrations of ordinary brick and stone houses are very short, still in view of the possible great suddenness of a destructive earthquake we should advise that all buildings be kept as low and made as rigid as possible.

The argument used by engineers to support the practice above referred to of placing a heavy top on a chimney assumes that the shock is an impact, and, consequently, that a definite quantity of momentum is given to the structure, but it must be quite evident that it is the relative velocity of the base of the structure with regard to the other parts which is the fixed quantity, and, therefore, that the more massive the structure the more momentum enters it through the base.

There is no easy way of judging what are the forces which cause an ordinary Japanese house to return to the perpendicular position after it has received a push or blow, and so we cannot calculate its natural time of vibration; but it is well known that it vibrates very slowly, an ordinary Japanese two-storied house with the usual heavy roof taking perhaps four seconds to make a complete vibration. The restoring forces are due merely to stiffness of the joints, there being no rigid connection with the ground since the vertical posts of the house are all supported on detached stones, and there are also no diagonal stays in the building. Such a structure is therefore capable of being displaced very far from its position of equilibrium without fracture occurring, and as its time of vibration is very long, it has a very great amplitude of swing during most ordinary earthquakes; that this amplitude is not even greater is most probably due to the fact that there is a sort of viscous resistance to motion at all its joints. Such a viscous resistance must greatly diminish the motion, and will be especially useful in an earthquake consisting of regular vibrations, but the most severe test of such a structure consists in an earthquake shock which begins with a sharp impulse, or which has a very irregular motion. The slowly vibrating structure would register the shock in a longer period of time than that in which the blow was delivered, but it would probably have an exceedingly great first swing from its position of rest.

We think that the important elements of safety in ordinary Japanese structures is this viscous resistance which they oppose to motion, and which is mainly due to the great multiplicity of joints (all of which are compelled to move) and to the absence of diagonal pieces; for we deduced from the principle in our original paper, that if the restoring forces are weak there ought to be a great viscous resistance to motion if we wish the strains of the structure to be small. But it must be remembered that this safety is only gained by a very great expenditure of timber, so that although such slowly vibrating structures as many of the temples may be regarded as exceedingly safe during earthquakes, it must not be concluded that all heavily-roofed houses are secure.

The amount of momentum which has to be transmitted through the foundations of a building to the superstructure depends on the nature of the earthquake —that is, its suddenness and the amount of earth motion, as well as on the mass of the building, while the velocity of the foundations, if these are rigidly con-

nected with the earth, is independent of the mass of the building, an important fact to which we have already drawn attention. The earthquake energy gets destroyed by the interior portions of the earth as well as the mountains and buildings at its surface, not having exceedingly small periodic times of vibration, in consequence of which interference takes place at every surface of contact of the different portions. Of course, however, any one particular building will destroy only a very small portion of the whole energy of the earthquake vibration, so that its mass cannot in any preceptible way affect the motions of its foundations.

In the same way as we have shown that the more quickly a house is capable of vibrating the less is its motion relative to the foundation, we might arrive at the result that the smaller the natural period of vibration of the several portions of a body subjected to shocks the less internal friction must there be; and this conclusion is consistent with the well-known fact that there is more internal friction in non-homogeneous bodies, or rather, we should say, in bodies which, being non-homogeneous, have some of their materials only capable of very slow natural vibrations compared with the remainder.

We have no doubt but that with any given material whatever there is a best method of constructing buildings in an earthquake country. Thus with small stones set in bad mortar, or in no mortar, as in the buildings destroyed by the Neapolitan earthquake of 1857, the momentum which must pass through any level joint depends (1) on the short time t during which the foundations are acquiring a great velocity v; (2) on the mass of the building M above the joint; and (3) on the natural time of vibration of the portion of the structure between the given joint and the foundations. If this time of vibration is very short then the momentum Mv must be transmitted by the joint in the short time t—that is, the joint must transmit the great force $\frac{Mv}{t}$; whereas if the time of vibration of the building below the joint is considerable, the time of transmission of momentum is increased in a calculable way, say to the time nt, and hence the force transmitted by the joint becomes reduced to $\frac{Mv}{nt}$. It is for this reason that if we wish to drive in a nail without hurting the head with the hammer a block of wood is used as a cushion, the wood being of service because having an appreciable time of vibration it causes the duration of the impact to be lengthened, and so diminishes the force acting at any moment. In the same way the lower parts of a structure having appreciable times of vibration cause the earthquake shock to be altered in character, to be lengthened in time, and, therefore, diminished in intensity before it reaches the upper parts. Hence it is obvious that if small stones or bricks set in bad common mortar are our building materials it would be better to choose, for the site, a quaking bog, which was capable of supporting the weight of the building, rather than to build the house direct from a rocky foundation, or if the ground is firm there ought to be placed underneath the house a foundation of yielding timber, or some other method should be sought for by means of which the time of transmissions of momentum through the joints may be increased.

Thus there is a best time of vibration of the part of a structure below a joint, which depends on the strength of the joint; and if the basement has a time of vibration different from this, then, we should advise that the building be kept low. For example, it is desirable that houses with ordinary wall thicknesses built of bricks set in common mortar should not be more than one, or at the very most two stories high if there is a piled or concrete foundation; but if good cement be employed instead of bad mortar, then a height of two or three stories may be employed probably with comparative safety.

Again, the horizontal vibration of the ground is given up to a stone or brick building mainly by shearing stress communicated from course to course, a kind of stress which mortar is very unsuitable to transmit. Hence, a stone or brick building subjected to horizontal shocks ought certainly to be built with cement, and not with ordinary mortar. In fact, in every part it ought to be capable of resisting pulling as well as crushing stresses.

Every joint is a weak place, and it is evident that if, by increasing the size of the building, we diminish the area of joints we shall be increasing the stability. Now, in large masonry structures larger stones are as a rule employed, and the joints are made of less area. In this respect, then, may we say that large masonry structures built with common mortar are usually more stable than smaller ones.

It is quite evident that, as concrete can be obtained which will resist as great a tensile stress as ordinary brick itself, we shall derive great benefit from making all horizontal sections of a structure, which is composed of bricks set in good cement, as great as possible—that is, we shall find that the most suitable structure, if of brick or stone, for an earthquake country, should be composed of large stones set in good cement, with walls as thick as possible near the base, the thickness of wall at every place being roughly proportional to the mass of the building above that place.

As, however, the resistance to tension of timber is very much superior to that of cement or bricks, and as the mass of a timber building is small, a timber building with sufficiently strong joints must be very much superior to any structure of brick or masonry. And, for the same reason, a building of wrought iron might be made stronger still, and one of steel strongest of all.

Ordinary timber houses ought not to be too rigidly fastened to the earth; if the joints of the structure are made, however, very strong, and especially if wrought iron is used as well as wood, and if there is diagonal bracing, then the connections with the ground may be made more rigid. The stiffnesses of structures vary so much that we cannot give more definite rules than those contained in this short article, but it is obvious that our principle of relative vibrations may be easily applied to find the best arrangement in a structure for any given material, and with any given foundation.

STEEL SHIPS.

From "The Nautical Magazine."

We have reluctantly felt compelled to place the heading "Steel Ships" before this paper, but would desire to repeat our former observation that the new metal is not *steel* at all, but merely *ingot iron.* Our readers will pardon this reiteration when they are told that some great authorities on the subject have been so far led away by the name as to adduce experience of the wear of some decided steel ships which have been afloat for years, as proof of the reliableness of the new metal of an essentially different character, although bearing the same name. So far as its composition goes the new metal is rather an exceptionally pure iron than a steel, and for aught we know at present, may ultimately develope qualities the reverse of those of ordinary steel. The cautions recommended in using it, and the careful testing of each plate, are rendered necessary by the fact that in the present state of the new processes of manufacture we cannot without test be absolutely certain that the metal obtained is the real *bona fide* ingot iron or mild steel. Mr. Wimshurst suggests that in consequence of the great ductility of the new metal, the ordinary system of riveting may be found insufficient, but wisely does not lay down any rules to be followed, and concludes with the excellent practical suggestion that in all cases of passenger ships built of mild steel "frequent easily made surveys should be held during the first year," which surveys "need not be of such a character as to interfere in the least with the engagements of the vessel, but they will afford the Board a prompt and effective means of checking any evil which may be found to arise."

We have, in our present paper, to notice a lengthy and important commun-

ication made to the Institution of Naval Architects, by the Chief Surveyor to Lloyd's Registry, on the subject, and giving in great detail the result of a series of experiments instituted by the Committee of Lloyd's Register. Mr. Martell begins his paper by some remarks upon the prospects of the general adoption of the new material, and appears to regard the question as practically settled. He says, "The time has now come when it is said by many others, besides the manufacturers, that steel can be used with as much confidence as iron, and it is held that whilst the properties of mild steel are in every respect superior to iron, the cost, having regard to the reduced weight required, will warrant the shipowner, from a commercial point of view, in adopting the lighter and stronger material." We have also the important fact that during the last twelve months the Committee of Lloyd's have had before them proposals for 5,000 tons of sailing ships, and 18,000 tons of steamers, to be built of mild steel.

We are glad to hear that, so far as they have gone, Lloyd's fully agree with the Admiralty as to the practical value of mild steel. As regards its working qualities Mr. Martell produced a specimen "shingled" from cuttings of plates which were in use, and which had stood a tensile strain of 26 tons per square inch. Experiment proved that its behaviour in the fire and under the hammer was just that of ordinary iron: in fact, the welds were cleaner and more perfect. The first series of experiments were made upon the strength of riveted joints, the results being, briefly, that iron plates double-chain riveted with iron rivets, the holes being punched, developed a mean tensile strength of 17.9 tons per square inch. Steel plates connected with iron rivets gave out by shearing of the rivets at a strain 16.7 tons per square inch of rivet area, the strain upon the plate only reaching 15.3 per square inch. Steel plates connected with steel rivets developed a mean strength of 22.5 tons per square inch. The result of these experiments, if borne out by similar results with more extended experience, will be to prove, that in using iron rivets with steel plates we must have a larger proportion of rivet area to the plate area between the holes for double riveting, or the plates must be treble riveted unless it be found that steel rivets can be used with good results, in which case the ordinary scale of riveting will be sufficient. As regards the practical use of steel rivets, in addition to the practical experience at Glasgow to which we adverted in our former article, Mr. Martell states that they have been recently satisfactorily used in two steel vessels, built by Messrs. Laird, of Birkenhead. Special care must however be taken to make sure that the rivets are really *mild* steel, and even then it is desirable that they be uniformly heated, and not at too high a temperature. As an illustration of this, a case is adduced where some builders tried steel rivets, and found that after some landing edges of outside plating had been riveted, many rivets were broken mostly between the plates; and in this case iron rivets were ultimately used throughout the vessel. Subsequent experience has shown that mild steel rivets can be safely used by ordinary riveters, and what is more, with the ordinary rivet boys; and we must conclude, therefore, that the rivets which failed were not made of true mild steel.

A second series of experiments were undertaken with a view to ascertaining the relative effect of punching upon mild steel and upon iron plates. The results are thus summarized:

"1. That steel plates very thin suffer less from punching than iron.

"2. That the difference in loss of strength by punching on steel and iron does not appear sufficiently great to require special precautions to be taken for steel more than for iron in plates up to $\frac{8}{16}$ inch in thickness.

"3. That in plates above eight-sixteenths in thickness, the loss of strength of iron plates by punching ranged from twenty to twenty-three per cent., while in steel plates of the same thicknes it ranged from twenty two to thirty-three per cent. of the original strength of the plate between the rivet holes. An occasional plate, both of iron and steel, showed a smaller loss than the minimum stated, but they were exceptional cases.

"4. That by annealing after punching, the whole of the lost strength was restored, and in some instances greater

relative strength was obtained than existed in the original plates.

"5. That the steel was injured only a small distance around the punched holes, and that by riming with a larger drill than the punch, from $\frac{1}{16}$ inch to $\frac{1}{8}$ inch around the holes, the injured part was removed, and no loss of strength was then observable, any more than if the hole had been drilled.

"6. That in drilled plates, no appreciable loss of tensile strength was observed."

Mr. Martell then, at some length, considers the respective disadvantages of riming the holes or annealing the plates. He also shows that, even after allowing the twenty per cent. less scantling for steel, and supposing a further loss of thirty per cent. by punching the plates, as compared with the twenty per cent. loss due to punching in ordinary iron, the advantage is still with the steel. A better solution of the difficulty than annealing will probably be found in the use of some kind of punch which will distress the iron less than the common one does. Some of the experiments proved that the loss due to punching, when the patent spiral punch was used, was $2\frac{1}{2}$ tons per square inch less than with the common punch.

The second part of Mr. Martell's paper is devoted to the question of the relative cost of vessels built of mild steel and of iron, taking into the question the reduced weight of hull and consequent larger carrying capacity of the former. In the first place, he disposes of the objection that mild steel is of so much greater specific gravity than iron as to detract considerably from the advantage of the smaller scantlings offered by Lloyd's. It has been said that the difference was as much as 4 per cent., data furnished by Messrs. John Brown & Co., the well-known Sheffield firm, fix it at 2.66 per cent., and Mr. Bessemer states it to be still less. Mr. Martell goes into details as to the first cost, and subsequent yearly profit of a steamer 2,300 tons gross, supposed to be built for the Indian trade, and makes out that with a cargo of coals out and measurement goods home, the additional freight of the steel ship would just pay the percentage on her additional cost, but with a dead weight cargo out and home there would be a profit on the voyage of $6\frac{3}{4}$ per cent. in the steel ship as against $5\frac{1}{2}$ on the iron ship. With sailing ships the gain is not so clear, although, from the fact that a sailing vessel of 1,700 tons is now being built of the new material, it would appear that at least one large shipowner believes that even in the case of sailing vessels the additional freight would pay interest on the additional cost. Obviously a saving of weight in the structure is of very much more importance in a steamer than in a sailing ship; in the former, the machinery and coals absorb so much of the carrying capacity that the addition of a few tons to the freight gives a larger percentage on the total freight.

As regards the durability of the new material, Mr. Martell can tell us little more than has been known for some time past. We agree with him that the fact that the Admiralty are going to build some small torpedo vessels of brass or bronze instead of steel is nothing to the point. It has been found that some of the thin steel torpedo vessels have in a very short time become very much pitted; it must be remembered, however, that they are only $\frac{1}{16}$ inch thick, and an amount of deterioration hardly noticeable in another vessel would be serious in them. Less to the point are the other remarks as to the durability of some vessels built of steel some years ago, and which have worn well. It cannot be too much insisted upon that these vessels were built of *bona fide* steel, whereas the new metal, mild steel, in some of its properties, is much more analogous to wrought iron than to steel. Especially is such the case in the most important feature, as regards decay. The chemical analysis of mild steel shows a larger percentage of pure metallic iron than is found in any commercial wrought iron.

Probably with the increased demand for mild ship steel the cost of production may, in a few years, be so diminished that it may successfully compete with wrought iron for all kinds of ships. At present it will probably be used in many steamers, more especially in vessels designed for speed, in which, as compared with ordinary steamers, every ton of increased freight is of as much greater importance, as in the comparison between ordinary steamers and sailing ships.

THE BRAKE AS A DYNAMOMETER.

From "The Engineer."

The friction brake is so generally regarded as an essentially accurate instrument for ascertaining the power developed by a steam engine or water wheel, that it requires some courage even to suggest that it is perhaps not quite such an instrument of precision, after all, as some persons would have us think. The friction brake is more used by builders of portable engines than by anyone else. There is scarcely a respectable agricultural engineering works in the kingdom in which the friction brake is not regularly and frequently employed. But the great majority of mechanical engineers engaged in the construction of marine engines, locomotives, or stationary engines of large power, know nothing practically about it. It is, therefore, to the experience of agricultural engineers that we must turn for such information as may enable us to form an estimate of the true value of the friction brake as a power-testing machine; the remainder of the engineering community can, as we have said, tell us nothing whatever that is not theoretical about it. Now it so happens that many agricultural engineers say that they have found by experience that the friction brake is by no means so precise an instrument as theory would have us believe. Indeed, unless these gentlemen are wholly mistaken, the brake may, theory to the contrary notwithstanding, prove very deceptive. Everything, it it is said, depends on the condition of the brake. If that is perfect, then a high duty can be got from an engine; if it is imperfect, then the performance of the engine will be bad. To explain our meaning, it is necessary to go back to the days when prizes were given by the Royal Agricultural Society for portable engines. The competing engines were made and tested daily for months before they came to the public trial. Now, it was well known to those who superintended the daily runs made with a racing portable engine, that whereas on some occasions a run of, say, four hours could be obtained with 14 lbs. of coal per brake horsepower, on other days the run would not exceed three and a-half or three and three-quarter hours, and there was no possible explanation of the circumstance save that the brake did not work smoothly. Carrying this experience into practice, engineers always did their best when competing publicly, to get a brake which had been worked until it was in perfect order; and some of the most eminent authorities on racing portable engines maintained that the difference between a brake in what is known as a good condition and one in bad condition may be such as to affect the length of a run by from five to ten minutes.

Such conclusions and experiences as we have just noticed are totally opposed to the received theory of the friction brake; yet it is impossible to ignore them, and it may be found that the apparent incompatibility may be reconciled by adding something to the theory which is in no way opposed to physical truth. The friction brake or dynamometer consists of a smooth pulley some 5 feet in diameter, round which run two hoops of iron lined with blocks of elm, beech, or willow. The hoops can be tightened by a hand screw, and when so tightened would, if permitted, revolve with the pulley. To prevent this they are fitted with a simple lever arragement by which the straps are slackened if they move through a short distance with the pulley, and at one side of the ring of wood blocks is suspended a weight, calculated according to the power required. This weight is kept in suspension the whole time that the pulley is running, its weight being just sufficient to equal the frictional resistance of the blocks on the rim of the pulley. This being so, it is assumed that the resistance offered to revolution by the apparatus will exactly equal the power that would be required to wind the weight on the brake out of a pit, say, of great depth. Let the distance from the point at which the break load is suspended to the center of the brake pulley shaft be such that, using it as a radius, a circle 33 feet in circumference would be described, then for every 1 lb. of brake load and one revolution of

the brake pulley 33 foot-pounds of work will be done. Let the revolutions of the brake be 100 per minute, then every pound of brake load represents $33 \times 100 \times 1 = 3300$, and every 10 lbs. of brake load becomes $33 \times 100 \times 10 = 33,000$ foot-pounds per minute=one horse power. It will be seen that the apparently absolute measure of the work done is the load on the brake and the surface speed. The maximum resistance the engine can have to overcome is measured by the weight, because if the hand screw is tightened the weight will rise, and would be carried round with the wheel but for the levers before referred to; while, on the other hand, if the straps were released, the weight would fall a little until the straps automatically tightened it again. According to theory, again, the condition of the brake has nothing to do with the matter. If the surfaces of the pulley and the wood blocks are rough, then the hoops must be left a little slack. If, on the other hand, the surfaces are beautifully smooth and well oiled, then the hoop must be tighter, but in either case the resistance offered to the engine is precisely the same, and is measured by the weight which hangs balanced in mid-air while the engine is running. There can be no doubt that this reasoning is extremely plausible, and would be quite convincing if it only covered the whole of the ground to be traversed. But let us ask ourselves what becomes of the power developed by the engine? No useful work is done; the weight is not lifted, and the only reply is that the power is transformed into heat; that is to say, the engine heats up the brake pulley and its connections, and it also heats up the water or oil used for lubrication. This heat is dissipated by conduction and radiation. It amounts to 42.75 thermal units per horse-power per minute.

An engine working up to 20-horse power develops as much heat in the brake as would rise from 62° to the boiling point 342 lbs., or say 34 gallons of water per hour. All this is quite intelligible, and a little examination will show that the engine, instead of lifting a weight, works against friction, and it is assumed that the weight is a precise measure of the amount of friction, or, to speak more accurately, of the quantity of heat which will be transferred per hour from the engine to the brake, and thence to the air and the lubricants. On this point the whole theory of the friction brake really turns, and unless it can be proved that a given weight resting on a polished surface running at a given speed beneath it can produce an amount of heating which is invariable under all circumstances for the same conditions, then the theory of the brake must be regarded as incomplete. Hitherto almost all writers on this subject entirely neglect the consideration of the heat imparted to the brake. They allude to it, indeed, but only incidentally, and they say nothing whatever concerning the relation between the brake load and the heat developed. They content themselves with considering the duty done by the engine to be precisely similar to the work of lifting a weight, whereas they are totally dissimilar, and if it could be shown that under certain conditions a given brake load would convert greater or lesser quantities of engine power into heat, then the idea that the friction brake is thoroughly reliable dynamometer would have to be abandoned. It is well known to all who have had experience that friction brakes will run sometimes hot and sometimes cool, and, according to those whose experience constitutes the best authorities, *that the cooler a brake runs the smaller is the power required to work it.* If this be true, then it is evident that the usually received ideas concerning the merits of the brake as a dynamometer must undergo some modification.

It will be understood that we have advanced nothing concerning the friction brake which will not be confirmed by many engineers who have used it much. It is difficult to reject as valueless opinions which we have heard expressed over and over again for years, and the accuracy of which is suggested by our own experience. All that we have now endeavored to do is to show how it may be possible to reconcile theory and practice. It is certainly possible to conceive that under all possible circumstances the coefficient of friction need not bear an invariable relation to each other. Let us suppose that the coefficient of friction of well lubricated wood blocks is $\frac{1}{80}$, and that the weight to be supported is 100 lbs.

then the blocks must be applied to the wheel with a force of 5000 lbs., and the heat developed on the brake per minute will be 427.5 units. Now it is absolutely certain that the conditions of speed, load &c., being constant, the rate of conversion of power into heat must also be constant. In other words, is there an invariable relation between frictional resistance and heat developed? That an approximate relation does exist we do not for a moment question, but that anything like an invariable correspondence can be proved to exist, is open to question. Those who have the means of settling the point by actual experiment should do so. The friction dynamometer is no doubt a substantially accurate machine ; but if a legal difficulty arose to-morrow about the power of an engine, a jury would soon have reason to believe that even under the best arrangements the friction brake may be as much as perhaps 10 per cent. wrong in its indications.

REPORTS OF ENGINEERING SOCIETIES.

The Institution of Mechanical Engineers, held meetings in Paris in June. The following papers were read:

Further Researches on the "Flow of Solids"; by M. Henri Tresca, President of the Société des Ingenieurs Civils.

On the Hydraulic Machinery at Toulon Dockyard; by M. Marc Berrier Fontaine, Ingénieur de la Marine, Toulon.

On Mechanical Traction upon Tramways; by M. Anatole Mallet, of Paris.

On the Greindl and other Rotary Pumps; by M. L. Poillon, of Paris.

On the Vapart Disintegrator; by M. Prosper Closson, of Paris.

On Compound Engines fitted with Correy's Variable Expansion Gear; by Mr. Thomas Powell, of Rouen.

On the Effect of Brakes upon Railway Trains; by Captain Douglas Galton, C.B., F.R.S., of London.

On Lighting by means of Electricity; by M. Hippolyte Fontaine, of Paris.

IRON AND STEEL NOTES.

Analyses of Russian Iron.—Mr. Sergius Kern has written from St. Petersburg commenting upon the remarks of Mr. E. Riley, that he was astonished that most of the steels, the analyses of which appeared in Mr. Kern's late paper, contained only traces of Ph. and S. Mr. Riley also complained that the percentage of Mn. was too low in the analyses, and added that perhaps Mr. Kern used inferior methods for the detection of Ph. S. and Mn. The following are the answers of Mr. Kern: "(1) The steels in question were prepared from Oural pig-irons; most of them, indeed, contain only *traces*, or *nil*, of Ph. and S. Charcoal is used as fuel. (2) The methods I use belong to Eggertz, and may be found in his classical manual 'Om Kemisk profning af Jern, Jernmalmer och Braenn materialier.' Using the methods of the well-known Professor V. Eggertz, I cannot understand why I should prefer other methods. (3) As for the low percentage of Mn., I will only mention that I cannot understand what Mr. Riley wishes, as it is not my fault that the Russian steels contain such a low percentage of Mn."

At the Philadelphia Exhibition, it will be remembered, an International Committee, consisting of commissioners who were over reporting for the different countries, had a discussion on the classification of iron and steel, and proposed new definitions. Among those on the committee were Mr. I. Lowthian Bell, M.P., F.R.S., and Dr. Reuleaux, of Berlin. The German Ironmasters' Association has, according to the *Iron and Coal Trades Journal*, just had this classification under discussion, and resolved :—(1) that a general classification of iron and steel is neither necessary nor useful ; (2) that the tests now customary for testing iron and steel goods—hammering, bending, and loading for rails, bending for axles, pulling for sheets, &c.—are sufficient ; (3) a specification of limits of value of the properties of iron and steel goods in reference to their uses is desirable ; (4) that a further prosecution of the experiments hitherto conducted by the association, with common commercial irons, is therefore desirable, in view to an eventual special classification of railway material ; (5) that State testing be placed under the control of a commission, consisting on the one part of delegates chosen by consumers and producers alike, and, on the other, of approved men of science ; (6) quantities of metal in railway contracts to be determined by ironmasters conjointly with the railway engineer ; (7) that the proposal made by Dr. Reuleaux, to draw up a table of properties, and stamp goods with a mark corresponding to a designation in the table, is impracticable.

Siemens-Martin Metal Ruled to be Steel.—Secretary Sherman has sent a letter to the Collector of Customs at Boston, Massachusetts, in which the vexed point of how Siemens-Martin metal is to be taxed, is disposed of. The text is as follows :—"The Department, by decision of December 1st, 1874 (Synopsis 2025), held that metal produced by what is known as the 'Martin-Siemens process' should be charged with the duty imposed upon steel, such process being considered a steel-making process, designed only to produce an article having the 'quality of steel.' Subsequently, upon further consideration, and upon additional facts at that time submitted, the Department, by letter of July 14th, 1876 (Synopsis 2891), expressed its conviction that both iron and steel are produced by the Martin-Siemens process, and that, consequently, the fact of manufacture by that process was not of itself

conclusive ground for classifying the product as steel; but that the question whether any particular importation was iron or steel was one of fact to be determined by the appraisers. It has recently been ascertained that a want of uniformity has prevailed at the ports of New York and Boston in the classification, since the later decision, of importations of metal produced by the Martin-Siemens process ; metal of that character, and similar in every respect, having been, without exception, classified at the first-named port as steel and at the latter as iron. In view of these facts, the Department has again had the matter under consideration, and has submitted the question of the character of this metal to experts, metallurgists, and the most prominent manufacturers of, and dealers in, iron and steel in the United States. A careful consideration of the reports and opinions of these persons satisfies the Department that the Martin-Siemens process was intended to be, and is essentially, a steel-making process, and that the product of such process must consequently be steel or an article possessing the general characteristics of steel, and used for the purposes to which steel is applied In confirmation of the correctness of this view, it may be stated that the classification at the port of New York of the metal in question as steel has been accepted without dissent by importers of that city, and that protest against payment of duty exacted on such classification has in no case been made. After a full examination and consideration of all the facts and information bearing upon the question at issue, the Department is of opinion that the classification as iron, of metal produced by the Martin-Siemens process, is erroneous, and that all metal produced by that process should be hereafter classified as steel, and assessed with duty accordingly. The decision of the Department of the 14th July, 1876, hereinbefore referred to, is therefore revoked, and decision 2025 will be regarded as in full force."

RAILWAY NOTES.

The St. Gothard Railway Co. finds some difficulty in obtaining the money necessary to complete its work. According to the original understanding under which the undertaking was begun, Italy was to have contributed $9,000,000; Switzerland, $4,000,000; the North German Confederation, $2,000,000; the Grand Duchy of Baden, $600,000, and the other German States the additional cost. Now Switzerland is asked to contribute as a nation, instead of by States, $1,300,000, on condition that the Northern & Central Railway Co. gives $300,000 more, which, it is estimated, will complete the road. Whether these subsidies are in addition to those originally agreed upon does not appear in the dispatch. The road will connect Luzerne and Milan by rail, and the division of cost between the nations is supposed to represent the proportion of benefits to be derived by each from its construction. It now requires fifteen fifteen hours to cross the Alps by the St. Gothard pass in the diligence from Fluelan to Bellinzona.

In discussing the recent half-yearly report of the Great Indian Peninsular Railway, Colonel Jas. Holland said :—"In the corresponding half of last year the proportion of English to native fuel used was 84 per cent. of English to 16 per cent. of native coal. Last half-year the proportion was 68 per cent. of English to 32 per cent. of native, so that we are coming to use native coal more considerably. I only wish I could say that the native fuel was as good as the English. It is, however, excepting that from Bengal, very inferior, but that, though good, is as dear as coal from England. It would shock any one accustomed to English coal to see with what rubbish from Wararo we work our line. It produces a vast quantity of sparks, and a considerable portion of the compensation paid for damage to goods has been owing to burning inferior coal. We find with the new and powerful engines now day by day coming upon the line that they puff and blow less ; the sparks are consequently fewer. We may now be said to be using about one-third native coal ; last year we used about 10,000 tons of native, this half-year we shall probably use about 30,000 tons."

The Belgian Grand Central Railway Company, in their annual report for 1877, publishes some statistical tables showing, for the period from 1865 to the end of 1876, the number of rails removed from the track, of those deteriorated but not removed from the track, removed and deteriorated, the number of remaining in the track uninjured, both of iron and steel. From these tables it appears that all the iron rails used before 1873 are of bad quality, except those laid in 1867, 1869, and 1870 ; these latter are hammered rails. Of the rails laid since 1873, the quantity removed is insignificant ; this is because for the past few years the management of the Grand Central makes sure of the quality of the rails, and purchases only of works which offer sufficient guarantees under this head. The quantity of rails in the track on the last of January, 1878, was 37,000 tons of iron, and 3385 tons of steel rails, and to maintain this track since 1865 has required 55,000 tons of iron, and 3388 tons of steel rails. Thus already 18,000 tons of iron rails have been renewed, and only *three* tons of steel. The greater part of the iron rails renewed are of those delivered in the years 1865, 1866, 1868, and 1871, which have been the worst, for of the 18,000 tons of iron rails removed, 12,600 were of the rails laid during these years. There have been broken 97 rails in all—94 of iron and 3 of steel. Comparing these figures with the whole number of rails of each kind in the tracks, we find that 0.04 per cent. of the total number of iron rails have been broken, and 0.02 per cent. of the total number of steel rails—that is, the number broken is in the proportion of steel to two iron rails ; and 68.04 per cent. of the breakages have been at the fish-bolt holes.

The Railroads of the United States in 1877.—From advance-sheets of *Poor's Manual* (the eleventh annual number) we take the following:

"The depression of the three previous years still continues. Not only has there been a considerable decline in the construction of railroads, but the earnings also show a larger relative decrease than at any period since the first publication of the *Manual*. The number of miles of railroad opened during the year 1877 was 2177, against 2657 for 1876, 1758 miles for 1875, and 2305 miles for 1874. The largest number of miles built has been in New York and Pennsylvania, and in narrow-gauge lines in Ohio, Iowa, and Texas. No new lines of any considerable magnitude have been undertaken. The tables which follow will show in what sections there has been any considerable increase.

"The gross earnings of all the roads whose operations have been reported have equaled $472,909,272, against $497,257,959 for 1876 and $503,065,505 for 1875. The general result of the operations of our railroads for the last seven years is shown in the following statement:

STATEMENT SHOWING MILES OF RAILROAD, CAPITAL ACCOUNT, EARNINGS, ETC., FOR SEVEN YEARS.

Year.	Miles operated.	Capital and funded debt.	Earnings. Gross.	Earnings. Net.	Earnings. From freight.	Earnings. From passengers.	Dividends.
		$	$	$	$	$	$
1877	74,112	4,568,597,248	472,909,272	170,976,697	342,859,222	130,050,050	58,556,312
1876	73,508	4,468,591,935	497,257,959	186,452,752	361,137,376	136,120,583	68,039,668
1875	71,759	4,415,631,630	503,065,505	185,506,438	363,960,234	13[illegible],105,271	74,294,208
1874	69,273	4,221,763,594	520,466,016	189,570,958	379,466,935	140,999,081	67,042,942
1873	66,237	3,784,543,034	526,419,935	183,810,562	389,035,508	137,384,427	67,120,709
1872	57,323	3,159,423,057	463,241,055	165,754,373	340,931,785	132,309,270	64,418,157
1871	44,614	2,664,627,645	405,329,208	141,746,404	294,430,322	108,898,886	56,456,681

"It will be seen by the above that the gross earnings have fallen off $25,348,687, and the net earnings $15,476,055, as compared with 1875.

"The ratio of net to gross earnings was 36.16 per cent., as against 37.5 per cent. for 1876, equal to an increase of 1.36 per cent. in the operating expenses, as compared with the preceding year. The decrease in earnings from freight has amounted to $18,278,154; and in passenger traffic, $6,070,533; the percentages of decrease being respectively 9.5 and 9.7 per cent. The dividends have fallen off $9,483,356; and are less than for any year since 1871. The total amount of capital stock on which dividends were actually paid was $835,038,896, giving an average rate of seven per cent. No dividends were paid on any of the railroads in the States of Arkansas, Colorado, Florida, Kansas, Louisiana, Mississippi, Missouri, Nebraska, Oregon, Texas and Vermont—nor excepting on leased lines in Iowa and Minnesota.

"The principal decrease in earnings has been in the Middle States, due partly to the depressed condition of the coal trade, and partly to the falling off in passenger earnings as compared with 1876, the Centennial year.

"The elaborate tables heretofore printed in the *Manual* are omitted this year; but the final results, the only important feature, are given in full detail. There is added a table reducing these results to the unit of 100. From this it will be seen that for each 100 miles of railroad in the United States there are 22.8 miles of second track, sidings, etc.; 20.1 locomotives; 15.2 passenger cars; 4.7 baggage, mail, and express cars; and 495.3 freight cars of all kinds.

"The capital stock aggregates, $2,921,507 for each 100 miles; the funded debt, $2,848,-308; the floating debt, $300,078; and the total cost of construction and equipment, $6,069,-893; equal about to $60,699 per mile of completed road.

"The gross earnings per mile were, $6380.94; operating expenses (63.85 per cent), $4074; net earnings, $2306.90. Interest paid on bonds per mile of road, $1248.04; dividends paid on stock, do. $739.52. The ratio of interest paid to total funded debt was 4.39 per cent; of dividends to aggregate capital stock, 2.53 per cent. In 1871, with only two thirds as many miles of railroad in operation, and a little more than one half the capital stock, the dividends aggregated $56,456,681, equaling 4.19 per cent. of the capital then invested.—*Engineering and Mining Journal.*

It is but a few years since the idea of bridging the Mississippi and Missouri rivers was held to be both impracticable and outrageous, as contemplating an infringements on the rights of navigations, and terrible pictures were drawn of the damage which would ensue to the boating and rafting interests if a single structure could be thrown over one of those streams. But the locomotive could not be kept back; one bridge was built and then another, and now there are no less than eleven structures—ten upon piers and one a pontoon bridge—spanning the father of waters between Winona and St. Louis. From a lengthy re-

port from a United States board of engineers, the *Railway Age* quotes the following list of these structures and their sizes:

At	When built.	No. spans.	Longest span, feet.	Draw.
Winona	1871	16	240	160
La Crosse	1876	10	240	160
Prairie du Chien	1875	—	Pontoons.	—
Dubuque	1868	8	240	160
Clinton	1865	14	180	118
Rock Island	1871	7	250	160
Burlington	1868	10	200	160
Keokuk	1870	12	240	160
Quincy	1868	24	160	160
Hannibal	1871	8	240	160
Louisiana	1873	11	256	200

ENGINEERING STRUCTURES.

THE Emperor of Brazil has recently written an autograph letter to Mr. James B. Eads, soliciting his advice in connection with the contemplated improvement of some of the great rivers in that country.

THE SUTRO TUNNEL.—This remarkable engineering enterprise will soon reach a successful termination.

The famous Comstock lode has been worked at a great expense, partly from difficult drainage and, partly from the high temperature, (120° F.)

Surveys made some years since indicated that a tunnel, nearly four miles in length, would lessen the difficulties and permit working to greater depths than would otherwise be possible.

The State of Nevada, in 1865, granted to Adolph Sutro the exclusive right for fifty years to run the proposed tunnel. A contract was made with all the leading companies, in which they agreed to pay $2 per ton for all the ore extracted after the main tunnel is complete and actually drains the mines; or, if they are not drained, then after a lateral drift reaches any mine. In 1866 the Federal Government granted the right of way through the public domain for seven miles along the Comstock lode; also the right to select 1,280 acres of land at the mouth of the tunnel, and the right or title to the mines for 2,000 feet on each side of the tunnel. All the mines of the Comstock lode are made tributary to the tunnel, the same as in the contract mentioned above. These measures were carried in response to recommendations and memorials signed by all the prominent mining officials, bankers, etc., on the Pacific Coast.

The tunnel has been in progress some eight years, and not far from $3,000,000 out of about $4,000,000 required to complete the work and its railway connections have been expended up to this date.

FOUNDATIONS FOR BRIDGES.—The system of making foundations for bridges in marshy soils, adopted by French engineers, in the case of the Charentes Railway—a line which crosses a peat valley to the junction of two small rivers —seems to have solved the problem of what is required in such cases. The thickness of peat at this point was so great that any attempt to reach the solid ground would have been extremely expensive. In order, therefore, to obtain a good support for the bridge, two large masses of ballast, accurately rammed, were made on each bank of the river, and a third on the peninsula between the two. The slopes of these heaps were pitched with dry stones, for preventing the sand from being washed away by the rains or by the floods in the rivers. Over the ballast a timber platform was laid, this platform carrying the girders of the bridge, which has two spans about sixty feet each. When some sinking down takes place the girders are easily kept to the proper level by packing the ballast under the timber platform—this platform packing being made by the plate-layers with their ordinary materials.

In another case—that of a railway in Algiers —a different plan of engineering was resorted to. This road crosses a peaty plane nearly a mile broad, the floods and elasticity of the ground preventing the formation of any embankment. The road was to be carried over a viaduct across the valley, but the foundations of this viaduct presented serious difficulties, the thickness of peat or of compressible ground being nearly eighty feet. It was quite possible to reach the solid ground with cast-iron tubes sunk with compressed air, or any other system; but neither the implements, the workmen, nor the material for such an undertaking were accessible in that region.

Under these circumstances, the engineers began boring holes ten inches in diameter down to the solid ground; these holes, lined with thin plate iron pipes, were afterward filled with concrete up to the very level of the ground. Each of these concrete columns bears a cast iron column, these columns being braced together in a suitable manner, thus supporting the girders of the viaduct.—*Railway Review.*

WIRE TRAMWAY WORKED BY WATER WHEELS.—The tramway connecting the town of Lausanne with its harbor Ouchy, on the lake of Geneva, consists of two lines of rail, and two trains which are connected by a wire rope. At the top of the tramway the rope passes over a winding drum, through which the trains are put in motion. The two trains keep each other in equilibrium, the one ascending upon one line while the other descends on the other line, and *vice versa.*

The tramway is 1,650 yards long, and leads in a straight line from Ouchy up to Lausanne, passing on the way a tunnel several hundred yards in length. The steepest gradient is 1 in 9.

The winding drum is driven by two Girard turbines, which work under a head of 393 feet; they are made of brass on account of the high velocity of the water, due to the great head; they have a diameter of seven feet four inches, and run at a speed of 170 revolutions per minute. The water can easily be turned on and off the turbines by means of circular slides worked by hydraulic gear.

The two turbines are fixed upon a horizontal shaft, which carries also a brake wheel, the band of which is worked by gears similar to

the slides, and spur gear for transmitting the motion to the winding drum.

The winding drum is 19 feet 8 inches in diameter and 13 feet long, and is covered with wood lagging. As it has to transmit by mere friction a force 180 H.P., making at the same time only a few revolutions per minute, the following arrangement to produce the necessary friction has been contrived by M. Callon, the designer of the tramway: The winding drum is placed in a position parallel to the direction of the tramway and considerably lower than the level of the rails; the rope is wound on the drum in two coils, and above the drum; the two ends of the rope are made to pass over two guide pulleys, which stand at right angles to the drum, and are carried in sliding bearings. By means of bevel gear and screw spindles, these pulleys are made to move to and fro along the winding drum, thus forcing the rope to travel continually from one end of the drum to the other, and preventing the surface of the latter from being worn smooth, as it would be if the coil were always on the same spot.—*Review.*

PUBLIC WORKS IN FRANCE.—M. de Freycinet, Minister of Public Works, is an able and ambitious man, and has lost no time in framing a project which was well calculated to excite the imagination of the French people. At the close of 1877 he had developed his plans, and on the 2d of January a project was laid before the Marshal President, which proposed to expend one hundred and twenty millions sterling upon the development and reorganization of the railway system in France. Nor was this all. Some days later a supplementary project was presented, demanding the expenditure of an additional forty millions sterling upon canals. An expenditure of one hundred and sixty millions sterling would be an arduous enterprise for even the most wealthy and actively prosperous of countries, but in a country which has been so depleted of capital as France has been within the present decade, it is a proposal demanding peculiar courage and coolness in those who make it. As must have been expected, it was assailed, not only by M. Rouher and others in the interests of the monopoly which the existing great companies practically enjoy, but by some advocates of the smaller companies, who are anxious to make better terms for their clients. M. de Freycinet's answer is practically a plea in "confession and avoidance." He admits that if the whole sum of 160 millions sterling were to be withdrawn at once from active use, and sunk in the construction or working of unproductive railways, the danger of a financial crisis might become imminent, but he points out that the expenditure will be gradual—will be spread, indeed, over ten years or more. Six commissions—one for each of the *réseaux* worked by the great companies—have been appointed to inquire whether the main systems of each of those companies may not be extended, and in a few weeks it is anticipated that they will have prepared their reports. When they have reported, the Ministry will be able to state with fair precision what the extent of the national railway system will be. The conjectures of well informed persons are to the effect that the Ministry, after the above-mentioned reports have been received, will state that provision must be made on national grounds for the maintenance of some 38,000 kilometers of railway in France. Of these "national lines" only about 21,000 kilometers are at present in working order; 5000 kilometers have been sanctioned by the Chambers, and private enterprise has undertaken 2000 more. But supposing all these projects to be carried out, there would still remain a deficiency of from 8,000 to 10,000 kilometers, for which new and additional provision must be made. In the same way, M. de Freycinet contends that the extension of the canal system ought to be provided for, and the reports of five commissioners appointed to inquire into the artificial waterways of the five great "catchment basins" of France will ultimately guide the Chambers. An expenditure of 30 millions on new canals and on the completion of old work, and of ten millions on the deepening and improvement of ports—such is the outline of M. de Freycinet's scheme, of which the bill now before the Chamber of Deputies is only the first and most modest installment. As for the financial plans with which the Minister of Public Works hopes to meet the new burdens he would impose upon his country, they are important enough to require separate consideration. It is enough to say now that they would involve the addition, according to M. de Freycinet's calculations, of seven millions sterling a year to the taxation of France.—*The Standard.*

ORDNANCE AND NAVAL.

NEW GATTLING GUNS.—Mr. Ackers, agent of Dr. Gattling, inventor of the mitrailleuse, tried at Sealand Range, Chester, recently, in the presence of Captain Rogers and a number of officers and men connected with the pensioners now up for training, three new patent Gattling guns, which have never before been tried in England. The mitrailleuses were first tried at 1000 yards range, Mr. Ackers working the machine. When everything had been arranged, the signal was given, and the weapon literally poured out a hail of bullets, the majority of which struck the canvas target and tore it all to shreds, and penetrated quite through 2-inch oak supporting poles. Accurate time was kept by Captain Rogers, and it was ascertained that the mitrailleuse fired 1000 rounds a minute, which is 300 to 400 rounds a minute faster than any other Gattling gun. Experiments with the weapon were then tried at 800 and 600 yards range, and the way in which the bullets were hurled at the target, and the marvelous precision with which they struck it astonished every one present. The sergeant-major who was working it said that a sparrow must have been killed flying across the line of fire: the bullets which fell a little short tore up the clods of earth and hurled them right over the target into the workmen's retreat. It was the opinion of competent judges that this is the most destructive weapon ever invented.

THE LOADING OF HEAVY GUNS.—To facilitate the loading of heavy guns it has been of advantage to enlarge the bore at the muzzle by half an inch or more by scooping out half an inch or so of metal for a depth of about two inches. This process is to be termed "bell mouthing," and it is to be applied to all the guns in the Service of ten inches and upwards. Artificers are being sent in various directions to make the alterations in the guns at the several forts and stations.

A NEW EXPLOSIVE.—It was stated at the last meeting of the Royal Dublin Society that a new explosive agent has been discovered by Professor Emerson Reynolds in the Laboratory of Trinity College, Dublin. It is a mixture of 75 per cent. of chlorate of potassium with 25 per cent. of a body called sulphurea. It is a white powder, which is very easily prepared by the mixture of the materials in the above-named proportions. The new powder can be ignited at a rather lower temperature than ordinary gunpowder, while the effects it produces are even more remarkable thon those caused by the usual mixture. Dr. Reynolds states that his powder leaves only 45 per cent. of solid residue, whereas common gunpowder leaves about 57 per cent. It has been used with success in small cannon, but its discoverer considered that its chief use would be for blasting, for shells, for torpedoes and for similar purposes. Dr. Reynolds pointed out that one of the advantages this powder possesses is that it can be produced at a moment's notice by a comparatively rough mixture of the materials, which can be stored and carried without risk so long as they are separate. The sulphurea, the chief component of the new explosive, was discovered by Dr. Reynolds about ten years ago, and could be easily procured in large quantities from a product of gas manufacture which is at present wasted.

A NEW ITALIAN IRONCLAD.—The ironclad Dandolo, which was launched at La Spezia, on Wednesday, is a sister ship of the Duilio, now completing for seas for the Italian Government. Both of them are to be armed with 100-ton guns, and destined to carry armour no less than 22 inches in thickness; so that, in point of armament, these Italian men-of-war bid fair to be the most formidable afloat when they are finished. Our Inflexible will not be so heavily armed as either the Dandolo or Duilio for her turrets are fitted to contain each of them a pair of 80-ton guns, while the metal of the Italians consists of four 100-ton cannon. On the other hand, the iron walls of the British ship are a little stouter, being 24 inches instead of 22 The Italian armor was devised to keep out shot from any cannon of less power than that carried by the ship itself, and this the plating practically does. The Duilio armour is capable of repelling all shot with the exception of that from an 80-ton or a 100-ton gun. The penetration of a 38-ton gun, the heaviest in our service at this moment, is set down at 19½ inches at a short range, and with the employment of a battering charge, and the Duilio, has its turrets protected with 22 inch plates. On the other hand, the 80-ton gun would make as little difficulty in getting through 22 inches of iron as 24, and there is little doubt nothing less than three feet of iron can be depended upon to stop the terrible blow of ¾ ton of metal hurled through the air at a speed of nearly a mile per second. The Italians have not been daunted, however. They have already set to work, and are now constructing two ships to carry armour plating capable of resisting any gun in existence. They hope to build a pair of turret vessels armored with 2 feet of solid iron, and to carry cannon of perhaps 200 tons. The names of these stupendous floating structures are the Italia and the Lepanto, but in the meantime Italy possesses in the Dandolo and Duilio two men-of war destined to carry heavier metal than any ship in the British Navy. The Dandolo was planned by the Commendator Brin, the ex-Minister of Marine The plates were constructed by Schneider of Creusot, and the engines by Maudslay, of London.

THE NEW FIELD GUN.—The new field-gun, which had, by a course of experiments extending over more than two years, undergone an evolution from a 9-pounder to a 12-pounder without enlarging its bore or materially increasing its weight, has undergone a further and final development, and may shortly be expected to appear as the model field-piece of the British Artillery in the shape and weight of a 13 pounder. Experience has proved that much of the value of a good field-gun lies in the length of barrel, and accordingly the 13-pounder, although no thicker than a 9-pounder, will be considerably longer than even the 16-pounder, the heavy gun of the field batteries of artillery, the efficiency of which is now admitted to have been sacrificed to the prejudice which existed at its introduction against impairing its symmetry by elongating the muzzle. The 13 pounder has undergone a rigid course of experiments. It is a compound of all the recent inventions, and it has produced splendid results.

SHELL PENETRATION.—Some trials of shell penetration of a very important character have lately been conducted at Shoeburyness under the direction of a committee appointed for the purpose. The experiments were in the nature of a competition between the shells of different makers, and hence, as they are to be resumed, it is not thought desirable that precise details should be published concerning them until they are completed. The general results obtained up to this point may be briefly stated. The object was to ascertain what shell would combine with the greatest power of penetration the power to retain its bursting charge in a state of efficiency. For this purpose the most eminent firms in England and on the Continent were invited to supply six shells each for a 9-inch Woolwich gun, the only restriction being that they were all to be of the same exterior and interior dimensions, the material and mode of manufacture being left to the discretion of the makers. Five English and four foreign firms entered into the competition, and three varieties of projectiles were sent from Woolwich—an ordinary Palliser chill-

ed iron shell, an improved chilled iron shell, and shell made from the much-extolled Gregorini iron from Italy. The gun used was an ordinary 9-inch Woolwich, with a charge of 65 pounds of powder, giving a striking velocity of 1500 feet per second. Every possible care was taken to obtain uniformity of strength and character in the plates fired at. These plates were made by Brown & Co., of Sheffield, were 12 inches thick, and of excellent quality throughout. Each of them was divided into pieces 4 feet square, and each competitor had a separate piece to fire each shell at. Each competitor fired two shells and the general result was that both the steel shells supplied by Sir Joseph Whitworth & Co, passed completely through the plate, and were left partially uninjured. All the others, especially those supplied by Herr Krupp and Herr Grusen wore broken to pieces by the impact, except the shells of the (French) Terre Noire Company which proved to be so soft that they bulged, and consequently retained so little penetrating power that the back of the plate was but little damaged. In every case, therefore, excepting that of the Whitworth steel, the projectiles were found to be valueless as shells for the purpose of penetrating armor and of retaining their bursting power after penetration.

QUICK STEAMING.—The famous torpedo boat Lightning, built by Messrs. Thorneycroft, has been beaten at last. Recently a trial was made by two launches constructed by Messrs. Yarrow & Co., of Poplar, for the Admiralty. The trials were carried out under the superintendence of Mr. Neil M'Dougall for the Admiralty. The boats are each 85 feet long, 11 feet beam, and draw 3 feet. They are strongly constructed of steel, and are fitted with compound surface-condensing engines capable of indicating 420-horse power. The high pressure steam cylinder of these engines is 12½ inches in diameter, and the low pressure 21½ in., both having a 12 inch stroke. These boats are at present known by their builders numbers, one being No. 419 and the other No. 420. The former is propelled by a three-bladed screw, 5 feet 6 inches in diameter and 5 feet pitch; and the latter by a two bladed screw of similar proportions. The trials were made over the measured two miles at Long Reach. No. 420 was first tried, and made the down run over the two mile course in 5 minutes 19 seconds, which is equal to a speed of 22.59 knots per hour. In other terms, this vessel attained the remarkable speed of 26 miles an hour. She had six tons of ballast on board, and her draught forward was 2 feet 8½ inches, and aft, 2 feet 7 inches, Her mean revolutions were 460 per minute; *maximum*, 475; steam pressure 120 pounds; vacuum 23 inches to 25 inches and blast 4 inches. The tide had just turned and was running out, being, therefore, with the vessel on the run down. On the run up it was of course against her. This run was made in 6 minutes 47 seconds, or equal to a speed of 17.69 knots per hour. The mean of the two runs was 20.14 knots, or 23.2 miles per hour. On the up run the mean revolutions were 460 per minute; the steam pressure 120 pounds; the vacuum, 24 inches; and the blast 4 inches. The vessel was under way just an hour, during which time she burned 10 cwt of coal, a portion of which was used in getting up steam. No. 419 was then tried. She was run light without any ballast, her draught forward being 2 feet 5 inches, and aft 2 feet 4 inches. The first run was made up the river, and, consequently, against the tide. The two miles were run in 6 minutes 38 seconds, giving a speed of 18.09 knots per hour. The mean revolutions were 459, the steam pressure 110 pounds; the vacuum 22 inches, and the blast 4½ inches. The second run was made down the river, and, consequently with the tide. Here the two miles were accomplished in 5 minutes 1 second, giving a speed of 23.92 knots or more than a knot faster than any run made by the Lightning, or 27.56 miles per hour. The mean of the two runs was a speed of 21 knots, or 24.2 miles per hour. On the last run the mean revolutions were 459, the steam pressure, 110 pounds; the vacuum 22 inches, and the blast 4¾ inches, This is by far the highest velocity ever obtained by a boat or ship of any dimensions or under any conditions.

TORPEDO WARFARE.—A remarkable series of experiments has just been concluded at Cherbourg by the successful completion of the three hours' trial of the last of a set of six torpedo vessels, which Messrs. Thornycroft & Co. have just delivered to the French Government. These vessels are somewhat similar to the improved "Lightnings" which that firm is now building for the English Admiralty, being 87 feet long over all, by 10 feet 6 inch beam, and drawing about 5 feet 6 inches of water. They are made of thicker plating than the original Lightning, and differ from her also in having the rudder placed abaft the screw—an arrangement which it was feared would occasion a considerable loss of speed in the vessels, and which was only introduced at the urgent request of the French Government. By somewhat modifying the construction of the hull and introducing some improvements in the machinery, which practically secured an increase of available power, this fear, as will be seen from the following statement of results, has been completely dissipated, and the boats have in some cases attained a higher speed than the Lightning did on her trial. The results actually obtained were as follows:

No. of Boat.	Speed on Measured Knot. Knots.	Speed on three hours' Run. Knots.
54	18.482	18.661
55	19.423	18.734
56	18.441	18.963
57	18 379	18.165
58	19.152	18.405
59	19.307	18.836

The runs on the measured knot, six in number for each boat, were made alongside the breakwater at Cherbourg, and the three hours' runs were made in the open sea between Cape la Hogue on the one hand and Barfleur on the other. The difference of speed as ascertained are accounted for by the condition of the bot-

toms of the boats and the state of the wind and sea on the days of trial. The speed contracted for was 18 knots per hour, so the contractors have amply fulfilled their obligations in that matter. The consumption of coal at full speed was found to vary from 18 cwt. to one ton per hour, and the bunkers were capable of containing five tons of coal. The actual amount of coal carried on the trials was only that required for a three hours' run. Steaming easily, the consumption was found to be very light—one of the vessels, having made the voyage from Chiswick to Cherbourg in 22 hours on a consumption of 2½ tons of coal. The weight on board, in addition to the three tons of coal required for steaming, consisted of a crew of ten men, with stores, &c., including even a spare propeller and a weight equivalent to the weight of the torpedo gear to be used on the vessel, and fixed in the position that the gear will occupy when the vessel is on service.

The primary object of the French in having these particular boats is, of course, the defence of Cherbourg; but it does not require a great amount of foresight to perceive that boats which are capable of steaming from one end of the Channel to the other and still having coal for a two or three hours' run at full speed will not be confined to the defence of any particular port, but will, in conjunction with larger vessels, be employed in offensive operations which will leave little to be done in the way of actual defence. Engineers and stokers accustomed to other classes of engines and boilers find some difficulty at first in getting the power, and consequently the speed, which Messrs. Thornycroft & Co.'s men obtain; but this is mainly a matter of practice, and the French officers of the "Défense Mobile" are most assiduous in their efforts to acquire information regarding their new boats, and to practice their men in the working of them. Organization is principally what is now required to convert these boats, when properly armed, into a most important means of national defence; and the well-known ability of the French in this way may be safely trusted to supply that want, so far as they are concerned.—*Times.*

Composite Armor Plates.—In continuation of the Admiralty experiments with armor plates, a composite plate, manufactured by Messrs. Cammell & Co. of the Cyclops Works, Sheffield, was subjected to gunnery tests on board the Nettle target ship, at Portsmouth Harbor. The experiments are to determine whether steel or composite plates, that is plates made with iron and steel, cannot be made of greater inpenetrability than the iron plates with which our war vessels are now coated. Already nearly a dozen plates have been in competition and notwithstanding each has represented from 300 pounds to 500 pounds the results obtained have not been altogether hopefull. The first experiments took place in the presence of a distinguished company including the Directors of Naval Ordnance and Naval Construction, and representatives of the German, Italian and Russian navies. Since that occasion, however, the experiments have been conducted in private, being only attended by practical delegates of the Admiralty able to gauge results of the trials. The above-mentioned plate was 8 feet long by 6 feet 8¾ inches in width, and 9 inches thick, its weight being slightly over eight tons. It was composed of 3½ inches of steel, and 5½ of iron. The plate was fixed to a transverse wood bulkhead built from side to side of the ship, and consisting of two vertical and two horizontal layers of oak bulks, making in all 3 feet 6 inches of thickness, the whole being shored by substantial wooden spalls secured by a massive thwartship. The gun used was a 12-ton 9-inch muzzle-loading rifle, and stood behind thwartship wooden bulkhead 30 feet from the plate. The charges were 50 pounds of battery pebble powder, and the projectiles chilled Palliser shots, 251 lbs. in weight, the muzzle velocity being 1420 feet per second, and the energy at the muzzle 3486 feet. Three rounds are usually fired at a plate and hitherto that number has done inevitable damage, but this plate was so comparatively invulnerable as to lead to two extra shots being fired to ascertain whether it was possible to break it up. The impact of the first three shots formed a triangular diagram, being about 2 feet apart. The first projectile struck the plate on the right hand side and penetrated nearly 7 inches, occasioning a series of superficial cracks. The impact of the next shot was on the lower section of the plate the penetration being a trifle more than 7 inches, and the further injury a fissure gradiating to the bottom of the plate, going quite home to the backing. The third shot made a number of cracks insignificant in their character, and penetrated 6½ inches. The depth of penetration needs to be explained for to those unacquainted with the previous experiments the idea may be conveyed that these tests were rather a failure. At ten yards distance, with so powerful a gun as a 12-ton 9-inch rifle, a shot penetrates clean through an iron plate, and partly through the backing, and in a lesser degree the same result has attended the experiments with composite plates, excepting in the case of that manufactured by Sir Joseph Whitworth, which was an extraordinarily expensive one, being studded with intensely hardened steel plugs. The fourth shot was aimed at the center of the triangular diagram, and partially broke the plate in two, the width of the fissure being ⅝ of an inch. Neither part, however, came away from the backing. The fifth projectile struck the right hand lower corner of the target and carried away the section bodily. All the five shots were smashed to fragments by the concussion, only their heads being imbedded in the plate. The experiments were conducted by Captain Herbert, of the gunnery ship Excellent. On Tuesday two more iron plates were received at Portsmouth Dockyard, one measuring 12 feet 8 inches by 4 feet 6 inches, its thickness being 10 inches, whilst the other's dimensions were 10 feet 5 inches by 4 feet 1½ inches, and its thickness only 2 inches. The former plate was manufactured by Messrs. Brown, of Sheffield, but the latter bears no maksr's name, although it is understood to have been forwarded by the same firm. Immediately after the receipt the

dockyard authorities telegraphed for instructions as to whether the plates were to be at once fixed into position for gunnery experiments.

BOOK NOTICES.

Geographical Surveying: its Methods, Uses and Results. By Frank De Yeaux Carpenter. New York: D. Van Nostrand. Price 50 cts.

This book is No. 37 of the Science Series. It is a report prepared originally as a part of the labor of a Commission for the Survey, Geological and Geographical, of the Empire of Brazil.

A complete discussion of the methods persued in the survey of large areas is presented in this little treatise.

The organization of the corps; the order of prosecution of different branches of the work; the comparative merits of different instruments, and the methods to be employed to secure the proper degree of completeness and accuracy without needless expenditure of time, are treated with a degree of fulness that leaves nothing to be desired by anyone familiar with the general methods of surveying.

The subject will interest many who are not of the engineering profession, since the results of the surveys of our great western plateau have called forth such flattering compliments from foreign scientific journals.

The Whitworth Papers. I, Plane Metallic Surfaces; II, An Uniform System of Screw Threads; III, A Standard Diurnal Measure of Length. By Joseph Whitworth, Esq., Manchester. Price 20 cts. For sale by D. Van Nostrand.

These brief essays are all included in one small pamphlet, which seems singularly disproportioned to the importance of the topics or to the eminence of the author.

Practical engineers, however, for whom these papers are designed, generally regard brevity in books with favor, and will find these essays none the less acceptable because they are inexpensive.

Railway Service: Trains and Stations. By Marshall M. Kirkman. New York: Railroad Gazette. Price $1.50.

This work treats of the composition and movement of railway trains and the laws governing the same, including an exposition of the duties of train and stationmen. The principal topics discussed are: The mysteries that underlie the organization and movement of trains; The different signals employed on different roads; Phraseology employed on English roads; Technical terms of a railway service; Classes and grades of trains and their movement; Instructions to conductors, brakemen, &c.; Rules regarding passenger and freight traffic; Austrian railways; English railways; General regulations for the block system on a double track road.

The work is well printed and will doubtless be of good service in aiding to harmonize different systems and improve in a general way the railroad management of the country.

Proceedings of the Institution of Civil Engineers.—Excerpt Minutes.

The following papers have been received through the kindness of Mr. James Forrest, Secretary:

The Steam Navy, comprising papers on its use, by Chas. Douglas Fox, M.I.C.E.; James Brand, A.I.C.E.; Henry Mitchell Whitley, A.I.C.E.; Charles Augustus Harrison, M.I.C.E.; also Remarks on Steam Excavating Apparatus, by Ruston, Proctor & Co.

Machine Tools, by Percy Ruskin Allen.

The Egremont Ferry-Landing, by William Carson, M.I.C.E.

The Hooghly Floating Bridge, by Bradford Leslie, M.I.C.E.

Drainage and Cultivation of the Albufera (Marshes) in Majorca, by Henry Robert Waring, M.I.C.E.

All the above papers, except the last, are fully illustrated.

MISCELLANEOUS.

Source of Error in Leveling.—Mr. G. C. Herron, Ottawa, Can., writes us as follows: "I have not seen mention made of the fact, in any book on Engineering, that when leveling over a hill or mountain the bubble will not assume a truly horizontal position; but will be at right angles to a line from its center to the center of gravity of the general mass of the earth and hill combined. This will cause the line of sight to rise in going up a hill and to fall in going down, and is a fruitful source of error in correct leveling."

M. Bardoux has opened at the Palais du Champ de Mars the Exhibition connected with Public Instruction. The minister said in his address that, owing to the recent progress of France, that country was now inferior to no other European nation as regards popular education. The results of the last conscription are highly satisfactory in this respect. Out of 294,382 men admitted into the ranks of the French army in 1877, only 4,992 were unable to read or write, 2,620 had taken their preliminary degrees in letters or sciences, 234,279 knew the "three R's," 36,325 could only read and write, and 5,856 could only read. Elementary schools have been established in the various regiments of the French army for years but the attendance, which had been very limited, is now almost universal. Not less than 305,989 soldiers were pupils of regimental schools in 1877; out of these, 255,380 followed the course of elementary instruction, 36,981 the secondary course, and 4,682 the course of superior instruction. The army has been turned into a machine for promoting elementary knowledge. In 1877 not less than 33,337 soldiers learned to read, 24,483 to write, and 111,303 were taught arithmetic. Under guidance of their officers, 200 soldiers from the garrisons of Paris visit the Exhibition daily.

"The supply of ice in Bombay has failed," was the announcement which greeted

the inhabitants of that city and the surrounding country about the middle of last month; and no one who has not experienced a week of life in India without ice can conceive the dismay with which the report was received. A large trade in ice is carried on between India and North American ports, Boston being the principal place of shipment, and, with the special arrangements made on board the vessels for keeping down the temperature, it is found cheaper to import it in this way than to make it artificially. The man who can devise some means of making ice by artificial means, in large quantities and at a sufficiently low cost, will make his fortune and confer an immense boon on those whose fate it is to dwell in countries beneath the sun. A little enterprise would probably open up a new field for the supply of ice for India in the Antarctic regions The lands and seas surrounding the South Pole require exploration, and a vessel destined to press the icebergs of that region into the service of the inhabitants of India would be able to drive a lucrative trade, and at the same time do science a service. It would hardly be possible, perhaps, to take a giant iceberg in tow, and haul it bodily into Bombay Harbor, but with the easy means afforded by dynamite of breaking up these floating monsters into suitable sizes for stowing on board ship, the neglected supplies might, thinks the *Colonies and India*, be utilized with comparatively little difficulty.

Le Neve Foster Testimonial Fund.—Some members of the S ciety of Arts, and others, who know the history and progress of the society during the last quarter of a century, and feel how much of its success during that long term has been due to the judgment, zeal and devotion of its chief executive officer, the secretary, Mr. Peter Le Neve Foster, have associated themselves together to present him, on the occasion of his completing twenty-five years' service, with a substantial testimonial in money, as an expression of their respect. Mr. Foster became secretary to the Society of Arts in 1853; the number of members at that time was little over 1,000, and the annual revenue scarcely exceeded £3,000; whilst in the year 1877 the number of members was nearly 4,000, and the revenue over £11,000. A reference to its "Journal" will show how many are the important public questions with which the society has successfully dealt during this period, questions in the initiation and conduct of which Mr. Foster has taken a prominent part. Education, elementary and technical, the reform of the patent and copyright laws, international exhibitions, public health, Indian and Colonial topics—these are but a few of the subjects on which Mr. Foster, through his connection with the society, has done useful work. On grounds such as these his friends confidently appeal to the members and to the public for their hearty co-operation. A committee has been formed to receive subscriptions, which may be paid to the credit of the Le Neve Foster Testimonial Fund, at Messrs. Robarts, Lubbock & Co., or at Messrs. Cocks, Biddulph & Co., or to the honorary secretaries and treasurers, at the offices of the Society of Arts, John Street, Adelphi.

One of the most remarkable occurrences which has come under our observation lately is the disappearance of a locomotive and tender beneath the quicksands of Kiowa Creek, Colorado.

The circumstances are somewhat as follows: An eastern-bound freight train on the Kansas Pacific road, on the 21st of May, plunged at full speed into the above named creek, the bridge having been washed away by a flood. The current was so strong that loaded cars and iron parts of the locomotive were washed five miles down stream, while the locomotive and tender disappeared altogether and were not found for more than two weeks afterwards, though diligent and constant search was made with long iron rods and otherwise daily. They were finally discovered, it is reported, by means of a magnet, which was carried over the surface of the sand and was finally attracted by the hidden iron. They are fifteen feet below the sand and twenty-five feet down stream below the bridge. Specific gravity accounts for the sinking of the locomotive through the quicksands, but in our judgment the movement down stream can only be accounted for by supposing that the whole mass of sand in the bed of the stream was in motion, like a glacier, and that the combined weight of the sand and the force of the current were sufficient to force this ponderous mass of iron, weighing perhaps twenty-five tons, the distance of twenty-five feet from where it fell. It is calculated that water moving at a velocity of 3,600 feet an hour carries fine gravel, and when moving at a rate of two miles carries coarse gravel and pebbles. Such being the case, a stream moving with a velocity of not less than five miles an hour in a bed of quicksand would doubtless move the whole mass with almost irresistible force. It must be remembered that nearly all of the time, the year round, the bed of the Kiowa is perfectly dry and that all the water that flows through it except during freshets, passes beneath the surface of the sand, and it is not unreasonable to suppose that the sand may thus be moved *en masse* when suddenly saturated by a swift and powerful stream. Doubtless the formation of the canons of the plains may be, in part at least, accounted for in this way.—*Western Review.*

The commission for reorganizing the Observatory of Paris has—says *Nature*—ended its sittings, as we have already reported. The commissioners recommended no change in the present organization of the Internal Meteorological Office; but, taking into consideration the actual wants of meteorology, it has advised the Minister of Public Instruction to appoint a meteorological commission, in order to suggest any measures which might be likely to promote the interests of meteorology at large, without interfering with the working of telegraphic weather forecasts sent by the International Office to the sea-ports and more than 1200 parishes all over France.

VAN NOSTRAND'S ECLECTIC ENGINEERING MAGAZINE.

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MAXIMUM STRESSES IN FRAMED BRIDGES.

By Prof. WM. CAIN, A.M., C.E.

Contributed to Van Nostrand's Magazine.

III.

108. Let us now compare the weights of the three trusses examined for the most economical heights. As the diameters of the columns are unchanged, the same number of pounds of iron for castings &c., was added as before. The section of the vertical posts in the triangular truss was taken at 4.5 square inches (see art. 87).

The trusses are all of 200′ span, with 12 panels. Assumed dead load 336,000 lbs ; live load 2,000 lbs. per foot, with two 60,000 lbs. weights, not less than 50′ apart, so placed as to give maximum strains in chords and web. The trusses, for the diameters of columns, strains per unit &c., given, are of the most economical heights ; all of them being through bridges with leaning end posts. The following is the comparison of weights:

Truss.	Fig.	Height.	Weight in lbs.
Triangular....	7	27	324909
Whipple......	9	29	325390
Pratt..........	5	26	333086

The comparison is thus most favorable to the Triangular, next to the Whipple, and least to the Pratt Truss, for the panel length &c., taken. Practically, the first two have the same weight.

109. An increase of the diameters of those columns that admit of it, would probably benefit the triangular most. Thus some of the interior posts of the Pratt or Whipple Trusses admit of little or no increase in diameter for a proper thickness of metal, whereas the main braces of the triangular do admit of it. With diameters of 15″ for upper chords and braces, the triangular may give the least weight; supposing the diameters of the upper chords of the other trusses to be 15″ also, the posts being enlarged where possible. On the contrary the workmanship towards the center of the space probably costs more for the triangular than for the others.

The heavy competition in this country has been productive of economy in material and workmanship, in bridge building, and the "bids" on the same design, often give the best comparisons between trusses of different types and details.

Each design has its advantages and disadvantages, and as a consequence its advocates and opposers.

A proper study of the details of trusses now before the country is then imperative.

110. It is interesting to ascertain what

inclinations of ties and braces will make the *web material* a minimum. Thus let Fig. 12 represent a panel of Fig. 11. Put AB$=l$, AC$=l_1$, BC$=l_2$, AD$=x$, DC$=h$; the dimensions being in inches.

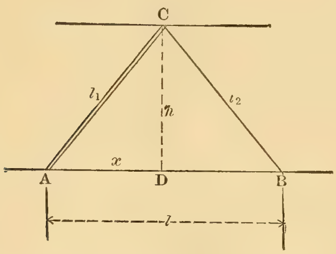
w''=weight of 1 cu. in. of tie BC in lbs.
w'=weight of 1 cu. in. of post AC in lbs.
c''=cost per pound of tie in cents.
c'=cost per pound of post in cents.
$b=7500\ (1+\theta)$=strain per sq. in. for tie.

$$b'=\frac{38500\ (1+\theta)}{4+\frac{l_1}{10d}+\frac{4cl_1^2}{r^2}+\frac{cl_1^3}{10dr^2}}=\text{safestrain}$$

per square inch for post,

as given by eq. (8), art. 53.

FIG. 12.



We find, S being the shear on the panel,

Strain on CB$=\mathrm{S}\frac{l_2}{h}$; cost CB$=\frac{\mathrm{S}l_2}{hb}.l_2w''c''$.

Strain on CA$=\mathrm{S}\frac{l_1}{h}$; cost CA$=\frac{\mathrm{S}l_1}{hb'}.l_1w'c'$.

Substituting for b and b' their values, we have as the total cost of tie CB and post CA,

$$\frac{\mathrm{S}}{100\ (1+\theta)h}\left\{\frac{l_2^2w''c''}{75}+\frac{l_1^2(4+\frac{l_1}{10d}+4c\frac{l_1^2}{r^2}+\frac{cl_1^3}{10dr^2})\ w'c'}{385}\right\}.$$

Placing $l_1=\sqrt{h^2+x^2}$; $l_2^2=h^2+(l-x)^2$; differentiating with respect to x and placing the result$=o$, we find that for *the least cost of tie and post* (on replacing $\sqrt{h^2+x^2}$ by l_1),

$$x=\frac{308\ w''c''l}{308w''c''+30w'c'(8+\frac{3l_1}{10d}+16c\frac{l_1^2}{r^2}+\frac{c\ l_1^3}{2dr^2})}$$

Examples.—1. Let $w''c''=w'c'$, $\frac{l_1}{d}=30$, and for a hollow cylindrical post hinged at both ends $c=\frac{1}{18000}$, $r^2=\frac{d^2}{8}=\frac{l_1^2}{7200}$, whence $x=.26\,l$.

If d is given, it is evident that h has only one value corresponding to $x=.26\ l$ to be found from the equation $\frac{l_1}{d}=30=\frac{\sqrt{h^2+x^2}}{d}$ $\therefore\ h=\sqrt{(30d)^2-x^2}$.

2. Similarly we find for $\frac{l_1}{d}=20\ x=.36l$; and for $\frac{l_1}{d}=40$, $x=.18l$.

111. If for b'' we write Rankine's formula with a constant factor of safety, 5,

$$\therefore\ b'=\tfrac{1}{5}.\frac{38500}{1+c\frac{l_1^2}{r^2}}$$

and proceed as before to deduce a formula, &c., we shall find by it that for

$$\frac{l_1}{d}=20,\ x=.36l$$
$$30,\ x=.3\ l$$
$$40,\ x=.24l$$

If in a Pratt truss (Fig. 5) of 200′ span, the *posts* as well as the ties are inclined so that $x=\frac{1}{4}l$, the web (neglecting the counter braces) weighs a few thousand pounds less than with vertical posts; the posts regarded as hinged at both ends in both cases. Using the value of b' in the previous article, for $\frac{l_1}{d}=30$ as an average, we found $x=\frac{1}{4}l$ for greatest economy. This is the value adopted in the Post truss and is, theoretically correct, for the above value of b', which is agreeable to practice as before mentioned. The *economy* of the square joint, however, due both to less workmanship as well as the use of a formula for posts with "flat ends" or "one pin ends" eliminates all saving in this direction.

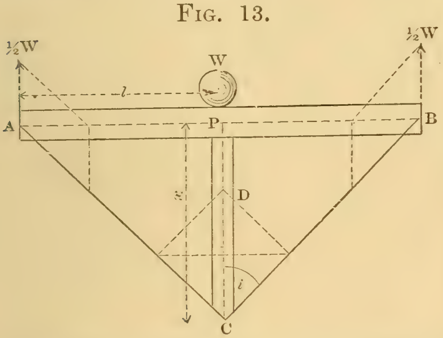
112. If the post is of wood $w'c'$ is very small compared with $w''c''$ and x is nearly equal to l. Hence in the Howe type (Fig. 6) the braces should be of wood—never of iron—for economy. Similarly, if the post AC is of cast iron, x ap-

proaches $\frac{1}{2}l$ as its proper theoretical value. The chords will influence the above results very slightly for usual diameters of upper chord.

113. For deck bridges and the triangular through truss, the shear on the post is greater than on the tie, and the post should be more nearly vertical. This supposition is easily included in the formula.

114. *Most Economical Depth for a Fink Element.*—Let a weight W act at P, Fig. 13. Call the constant length, $BP=AP=l$; the variable height of post $PC=x$; the strain per square inch on ties AC, BC, $=T$, on chord $AB=b'$, on post $PC=b$. The weight W is directly supported by the post PC.

FIG. 13.



Decomposing $W=DC$ at C, the strain on AC or BC is $\frac{1}{2}W$ $sec.\ i=\frac{W}{2}\frac{\sqrt{x^2+l^2}}{x}$.

This strain is in equilibrium at A or B with the reaction $\frac{1}{2}W$ and the chord resistance $\frac{1}{2}W$ $tan\ i=\frac{W}{2}\ \frac{l}{x}$.

On dividing the strain on each member by its strain per square inch and multiplying by the length of the member in inches, we get its volume. Thus the total volume of $AC+BC+PC+AB$ is

$$W\left(\frac{x^2+l^2}{Tx}+\frac{x}{b}+\frac{l^2}{xb'}\right), \textit{ to be a min.}$$

Now T is constant; also b', since l is constant, but b varies with x.

115. *Regarding b as constant;* on differentiating, &c., we readily find, *for a min. vol.*

$$\frac{l^2}{x^2}\left(\frac{1}{T}-\frac{1}{b'}\right)=\frac{1}{T}+\frac{1}{b}$$

$$\therefore\ tan.\ i=\frac{l}{x}=\sqrt{\frac{(b+T)\,b'}{(b'+T)\,b}}$$

Thus let $T=b'=10000$,

$b=10000$, $i=45°$
$b=\ 7000$, $i=47°47'$
$b=\ 6000$, $i=49°\ 3'$
$b=\ 5000$, $i=50°47'$
$b=\ 4000$, $i=52°55'$, &c.

116. Regarding $b=\dfrac{38500(1+\theta)}{\left(4+\frac{1}{10}\frac{x}{d}\right)\left(1+c\frac{x^2}{r^2}\right)}$

as variable we find,

$$tan.\ i=\frac{l}{x}=$$

$$\sqrt{\frac{b'T}{b'+T}\left\{\frac{4+\frac{x}{5d}+\frac{12cx^2}{r^2}+\frac{4}{10}\frac{cx^3}{dr^2}}{38500(1+\theta)}+\frac{1}{T}\right\}}$$

For a given $\frac{x}{d}$ we can of course find *tan. i;* but generally d is given and we can not know $\frac{x}{d}$ until x is found. Hence, given d, we cannot determine *tan i*, except by a series of approximations.

But as in the case of beam trusses, having assumed x and d, unless the preceding equality holds, the most economical depth has not been chosen, and the formula will indicate whether x is too small or the reverse.

Examples.—Let, $b'=T=10000$, and let PC be a hollow cylindrical column $\therefore\ \frac{x^2}{r^2}=\frac{8x^2}{d^2}$; $\frac{x^3}{dr^2}=\frac{8x^3}{d^3}$. Also place $c=\frac{1}{24000}$ and $\theta=\frac{1}{3}$.

Then for,

$\frac{x}{d}=20$, $tan.\ i=1.237\ \therefore\ i=51°\ 3'$

$\frac{x}{d}=30$, $tan.\ i=1.473\ \therefore\ i=55°50'$

$\frac{x}{d}=40$, $tan.\ i=1.761\ \therefore\ i=60°25'$

Thus somewhat shorter posts are required than when b is taken constant.

117. Let us now investigate a *Fink truss* (deck bridge) Fig. 14 for maximum strains and minimum material. Assume as before a 200′ span, but divide it into 16 panels of $12\frac{1}{2}'$ each. As before, let the weight of bridge=336000 lbs., or 10500 lbs. per panel on one truss; the car load, uniformly distributed, 1000 lbs.

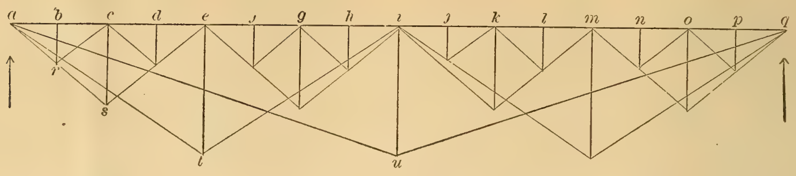


FIG. 14.

per foot or 12500 per panel for one truss, and the locomotive excess, two weights, 30000 pounds each for one truss and 50′ apart, to be so placed as to give maximum strains on chords, posts or chain system.

Each 30,000 pounds rests on 3 drivers for one truss, 6′ apart or a total wheel base of 12′ ∴ there is 10,000 pounds on each driver. *Hence when the center driver is at any post as c, the adjoining posts bear* $\frac{6}{12.5}$ 10,000=4800 *lbs., and the post c therefore* 30,000−9600=20400 *directly.*

118. If a weight is placed anywhere on $\overline{ac}$, since the element *arc* acts independently, *the reactions at a* and *c are determined by the law of the lever.* Similarly for the systems *ase*, *ati*, and *auq*; for the posts at the end of the system act as abutments to the system considered, and the reactions can only be determined by the simple law of the lever, irrespective of the pattern of the chain system used.

119. It follows, therefore, that the max. strains on posts *b*, *d*, *f* . . . . =1 panel dead and car load, (23000) + 20400 of loc. excess (center driver bearing on post)=43400 pounds.

The dead load is really less as the chains, *at*, *au* . . . only rest on *cs*, *ct* . . . ordinarily, but the section of the post would hardly be taken less than this strain gives, owing to oscillation of engine sometimes increasing the reaction at *b*, *d* . . . due to engine weight. But for posts *b* . . . put $\theta=\frac{5000}{43400}=.13$.

Next, let center driver bear at *c*.

The post *c* bears directly 23000 lbs. car and dead load+20400 loc. excess; also 23000+4800 transferred from *b* and *d*, making in all 71200 ∴ $\theta=\frac{21000}{71200}=.3$.

The post *e*, bears directly 43400+½ car and dead load at *b*, *c*, *d* and *f*, *g*, *h*, (69000)+(2.¾.4800+¼.4800) loc. weights borne at *d*, *f* and *h*=120800 lbs. *if* center driver is at *e*; but with locomotives at *c* and *g*, post *e* sustains ½ load on *a i*= 122000 lbs. which is therefore its max. strain; and $\theta=\frac{42}{122}=.34$.

If locomotives are supposed at *d* and *h*, the reaction at *e* due to them is (¾+¼) 30000=30000 as in the preceding case.

Lastly to find the max. strain borne by post *i*. It bears 8 panels, car and dead load (184000 lbs). With engines at *g* and *k*, by art. 118, post *i* bears ¾60000 loc. load. With engines at *h* and *l*, *i* sustains ⅞30000+⅝30000=$\frac{3}{2}$30000 as before; but with engines at *i* and *m*, *i* sustains ½30000+2⅞4800+20400=43800 or less than the 45000 before.

120. From the above we see that when one locomotive only can get on the system, it must be placed over the central post of that system to find its max. strains; when two locomotives can bear on one system they must be placed either side of the central post.

The above strains are entered in the following table. The max. strains on the ties at the foot of the posts are found by multiplying ½ the max. strains on posts by *sec. i*, *i* being the inclination of the tie to the vertical.

The lengths and diameters of posts are assumed as in the table.

It was not considered judicious to make the center post *i* longer than 30 diameters, though for theoretical economy it should be much longer.

121. *Chord Strains.*—As in art. 114, to find the chord strain due to any element we multiply ½ weight at foot of post by *tan. i.*

Thus for the uniformly distributed car and dead load of 23000 lbs. per panel, post *b* bears 23000 lbs; post *c*, 46000; post *e*, 92000 and post *i*, 184000 lbs. Similarly for similar posts so that the strain on *a q*, for uniform load is the same throughout and equals

Piece.	d	$\frac{l}{d}$	th	Strain.	θ.	b.	Area.	Length.	No.	k.	Weight.	Totals.
	″		″				□″	′			lbs.	
Post b........	6	20	$\frac{5}{16}$	43400	.13	6400	6.8	10	16	$\frac{10}{3}$	3627	
c........	11	22	$\frac{5}{16}$	71200	.30	6950	10.3	20	8	"	5493	
e........	$13\frac{1}{3}$	30	$\frac{1}{2}$	122000	.34	5670	21.5	$\frac{100}{3}$	4	"	9555	
i........	$13\frac{1}{3}$	30	1	229000	.37	5800	39.5	$\frac{100}{3}$	2	"	8778	27453
Tie ar........				34720	.13	8470	4.1	16	32	"	6997	
as........				56960	.30	9750	5.8	32	16	"	9898	
at........				109983	.34	10050	10.9	60.1	8	"	17469	
au........				362049	.37	10420	34.7	105.4	4	"	48765	83129
Chord aq.....	$13\frac{1}{3}$	11.3	$1\frac{3}{16}$	485625	.39	10140	47.9	200	2	"	63867	63867

$\frac{1}{2}(184000\times 3+92000\times 1\frac{1}{2}+46000 \times\frac{25}{20}+23000\times 1\frac{1}{4})=388125$ lbs.

122. Next consider the locomotive excesses, 50′ apart, consisting of 30000 lbs. each on 3 drivers. With center drivers at g and k, these posts support directly and indirectly 25200, the adjacent posts 4800 lbs each (art. 117) ; e and m, will bear 15000, and i 45000 lbs. applying the simple law of the lever to determine these reactions. This gives as the total strain on the parts $\overline{ei}$ or $\overline{im}$, due to loc. excess

$\frac{1}{2}(45000\times 3+15000\times 1\frac{1}{2}+25200\frac{25}{20}+4800\frac{25}{20})=97500$ lbs.

Similarly, for engines at e and i, the part $\overline{ci}$ experiences a strain of 92400 lbs. which differs but little from the preceding; hence I have regarded the chord $\overline{aq}$ as strained throughout by 97500 + 388125 = 485625 lbs. as entered in the table.

With engines at c and g, the chord strain on $\overline{ai}$ due to loc. excess is 86250 lbs.—less than in preceding cases.

123. The trusses were assumed 14′ from center to center; floor beams being 15.5′ long and 24″ deep; the web, $\frac{1}{3}''$ thick. The loss in the rivet holes is assumed equal in effect to the resistance afforded by the web &c. The floor beam max. live load is 63880 lbs. (see art. 15), to which add 6738 lbs. dead load. The moment at center is thus, $35309\times 54''=fda=7500\times 24\times 10.6$. The section of a floor beam is thus, 28.5 sq. in. and its weight 1472 lbs. Similarly the stringers of wood, each 16″×6.6 (see Fig. 9) or of iron I beams, 16″ deep, weigh about 213 lbs. per foot. The transverse bracing was put at 11400 lbs. as for the Whipple truss, the rails and cross ties as before. The "Whipple" deck truss, (art. 91) with which this one will be compared was subjected to as near the same conditions as possible, except that the panel length of the former was taken at $16\frac{2}{3}$ feet, whereas a different panel length might be more economical. The same percentages for castings, bolts, &c., was added to both.

The following is the

BILL OF MATERIALS.

Fink Deck Bridge, 200′ span, 16′ panels.

	lbs.
Ties...........................	83129
15 p. c........................	12469
Chord and posts................	91320
20 p. c........................	18264
Lateral tie rods and struts......	11400
17 Floor beams, 24″ deep......	25000
Wooden stingers...............	42600
Rails, cross ties, &c............	33200
Total weight of bridge....	317382
Assumed weight............	336000
Assumed weight too great by..	18,618

124. Let us now ascertain if each element of the truss has its most economical depth.

For the element arc, we must substitute in the value of $tan.\ i$ (art. 116), $T=8500$, $b'=10200$, $\frac{x}{d}=20$ and $\theta=.13$, as found from the table; whence we find that for the most economical depth $\frac{l}{x}=1.3$ $\therefore$ for $l=12.5$, $x=\overline{br}=9.6$ feet, As we assumed $\overline{br}=10$, the result is almost exact; in fact considering the thickness of chord, it is practically exact.

Similarly for the element ase: $T=9800$, $b'=10200$, $\theta=.3$, $\frac{x}{d}=22$ whence tan

$i=\frac{l}{x}=\frac{4}{3}$ ∴ for $l=25$, $x=\overline{cs}=18.8$ feet.

This value differs only 1.2 feet from the 20 feet assumed, or really only .6 foot say, considering the thickness of chord. The depth is very slightly too great.

For the element *ati*, $T=10050$ $b'=10140$, $\frac{x}{d}=30$ and $\theta=.34$, whence (see 2nd example, art. 116) $\frac{l}{x}=1.473$ ∴ for $l=50$, $x=et=33.9$, we assumed 33.3. Practically then, the most economical depths have been chosen for all the elements excepting *auq*, which is necessarily circumscribed in depth.

125. *The formula of art.* 98 applies directly to a Fink element, Fig. 13, since the chord strain varies directly as *tan. i* or *as the depth*, and the shearing force, $\frac{1}{2}$ W, is the same on the ties of Fig. 13 for any depth; these being the only requirements of the formula.

For a Fink element, Fig. 13, formula (14), art. 98, takes now the following shape,

$$W_c=W_t\ cos.\ 2\ i+W_p\ (1+m);$$

in which

W_c=Weight of chord A B

W_t=Weight of ties AC+CB.

and

W_p=Weight of post PC.

In the value of m, for hollow cylindrical posts, hinged at one end,

$$c\frac{l^2}{r^2}=\frac{1}{3000}\left(\frac{l}{d}\right)^2.$$

Now for the element *ati* Fig. 14, $i=56°19'$, $cos.\ 2i=-.385$.

From the table art. 120 we get $4\ W_t=17469$, $4\ W_p=9555$; and computing W_c we find $4\ W_c=(61000\times6\div10140)\frac{100}{3}=12030$. Also for $\frac{x}{d}=30, m=\frac{3}{7}+\frac{18}{39}$; whence

$$4\ W_c=12030>17469\times-.385$$
$$+9555\ (1+\tfrac{3}{7}+\tfrac{18}{39})=11235$$

The chord weight is very slightly too great, which indicates that the depth is too small for the most perfect economy; the same conclusion previously arrived at.

On comparing now the weight of the Fink with that of the Whipple deck bridge, (*art.* 91), *we see that the Fink is lighter by* 10,072 *lbs.*

126. *Fink Through Bridge.*—If we draw a line *tu* (Fig. 14) parallel to chord and drop "suspenders" from the foot of posts, as *r*, *s*, . . . to hold up the roadway *tu*, and also add vertical posts at *a* and *q*, the depth of the truss, we have an outline drawing of the Fink through bridge. Call the points of the roadway vertically under *a*, *b*, *c*, ... respectively *a'*, *b'*, *c'* . . . .; and consider the element *arc* conjointly with the suspender *rb'* for economy. Call $br=x$, $bb'=h$ ∴ $rb'=(h-x)$. As the post *br* only supports one panel upper chord, &c., its section will practically be taken much larger than the 2500 pounds about of dead load requires. Hence we can regard its section=S *constant* as *br* varies in length.

As in art. 114, call the strain per square inch on ties (*ar*, *rc*, *rb'*), T; on chord, b'. Then we have as in art. 114 the total volume of *ar*, *rc*, *b'r*, *ac* and *br* (calling W=load on suspender *b'r*),

$$W\left(\frac{x^2+l^2}{Tx}+\frac{h-x}{T}+\frac{l^2}{xb^1}\right)+Sx=a\ min.$$

whence,

$$\frac{l}{x}=\frac{bc}{br}=\sqrt{\frac{b'TS}{W(b'+T)}}$$

Now putting $S=4.5$, $b'=10000$, $T=8500$, $W=43400$, it follows that for economy that $x=l\div.685$. Thus if $l=12.5$, $x=br=18$. For $S=10$, $x=12.5$ feet, &c. The first values (nearly) are taken from the following table, and the results are thus correct for the element *arc*: but in the element *ase*, the cross section of *cs* must not be assumed constant for different depths. If it were, then it follows that for $b'=10{,}000$, $T=9700$, $W=71200$ and $S=8$ that $l=\frac{3}{4}\,x$ ∴ $x=33.3$ feet$=cs$. For $S=14$ (about), $x=l$.

It is easy to deduce a formula regarding b for the post *sc* as varying, but it is perhaps simpler to determine the proper value for *sc* by trial. From the formula above we see that as S diminishes, that the angle between the ties becomes less.

127. Let us assume as before that the ties *ar* and *as* are equally inclined, but place their inclination now at 45°, the depth of truss, no. panels, &c., being assumed as before.

The maximum strains on ties and top chord are determined as before, since they depend only upon the load borne at the foot of each post, whether that load is communicated by posts or suspenders or both.

The chord strain due to uniform car and dead load

$$=\tfrac{1}{2}(184000\times 3+92000\times 1\tfrac{1}{2}+46000+23000)=379500;$$

and that due to loc. excess placed at g' and k'

$$=\tfrac{1}{2}(45000\times 3+15000\times 1\tfrac{1}{2}+30000)=93750$$

The sum of the two is entered in the following table. With engine at b', post c bears about 41000 pounds. The posts e and i bear, one panel of car load (12500) + one panel roadway (3535), or 16035 pounds *less than before*, giving the max. loads ever borne by

Post e, $122000-16035=105965$
" i, $229000-16035=212965$

The dead loads carried by these posts are 17465, 38465 and 80465 so that θ has the respective values, 42, 36, 37.

The suspenders bear 32900 lbs. live load (=20400+12500) and 3100 lbs. roadway: in all 36000 lbs.

Piece.	d	$\frac{l}{d}$	th	Strain.	θ.	b	Area.	Length.	No.	k.	Weight.	Totals.
	$''$		$''$				$\square''$	$'$			lbs.	
Chord......	$13\frac{1}{3}$	11.3	$1\frac{3}{16}$	473250	.39	10140	46.7	200	2	$\frac{10}{3}$	62267	62267
Post *br*.....	5		$\frac{1}{4}$	2500	1.		3.6	12.5	16	"	2400	
cs.....	$7\frac{7}{8}$	37	$\frac{6}{16}$	41000	.42	4880	8.4	25	8	"	5600	
et.....	$13\frac{1}{3}$	30	$\frac{1}{2}$	105965	.36	5750	18.4	$\frac{100}{3}$	4	"	8180	
iu.....	$13\frac{1}{3}$	30	$\frac{11}{12}$	212965	.37	5800	35.5	$\frac{100}{3}$	2	"	7889	24069
Suspenders..				36000	.13	8470	4.3	20.8	16	"	4770	
" ..				36000	.13	8470	4 3	8.3	8	"	952	5722
Tie *ar*......	$\frac{43400}{2}\cdot\frac{35.4}{25}=$			30727	.13	8470	3.6	17.7	32	"	6797	
as......	$\frac{71200}{2}\cdot\frac{35.4}{35}=$			50410	.3	9750	5.2	35.4	16	"	9818	
at......	$\frac{122000}{2}\cdot\frac{60.1}{33.3}=$			109983	.34	10050	10.9	60 1	8	"	17469	
au......	$\frac{229000}{2}\cdot\frac{105.4}{33.3}=$			362049	.37	10420	34.7	105.4	4	"	48765	82849

128. With trusses 16′ apart, center to center, the iron floor beams, 26″ deep are estimated to weigh 1866 lbs. weight per panel; stringers and track as before 4738 lbs. We now form the following:

Bill of Materials.

Fink through bridge, 200′ span, 16 panels, 33′.3 deep.

	lbs.
Chain system and suspenders......	88571
15 p. c. for bolts, nuts, eyes and pins	13286
Chord and posts....................	86336
20 p. c. for castings................	17267
Floor beam loops...................	5000
Lateral rods, struts and portals. ...	15000
15 floor beams (26″ deep)..........	27990
Stringers (of wood)................	42600
Rails, cross ties, &c...............	33200
Total weight.....................	329250
Assumed weight....................	336000

The lateral struts and portals were increased over previous trusses examined by 4600 lbs. on account of the greater depth of this truss. The roadway for greater stability, should be formed of closely spaced cross bearers, extending from truss to truss, but we have *estimated* as above. If we subtract the weight of portals, say 5000 lbs. we get the weight of bridge for calculation 324,250 lbs.

The four-end posts or "pier towers," are 33.3 feet high and for 30 diameters weigh in all 17111 lbs. since they sustain a max. load of 226500, when train extends from farthest abutment to nearest panel. These pier towers should be given a broader base for equal stability with other trusses, and hence should weigh more than the above. Putting them at 17111 the total weight of bridge and towers is 346,361 lbs. which is more

than for the Pratt, Whipple or Triangular, previously examined.

129. To ascertain if the most econom ical depth has been chosen, let us keep the inclination of the ties, inclined 45,° at that angle. Then for a change of height $\triangle h$, only the suspenders, end posts and weights, due to systems *auq* and *ati*, need be examined. Call w_s = weight of suspenders of height $rb' = 20.8 = h_1$ then if the height of the truss $h = 33.3$ is increased by $\triangle h$, *the new weight of suspenders* is

$$w_s \frac{h_1 + \triangle h}{h_1} = w_s + w_s \frac{\triangle h}{h_1}$$

Similarly the new weight of the other suspenders whose height $= h_2 = 8.3$ is

$$w_s' + w_s' \frac{\triangle h}{h_2}$$

If these expressions are added to the value of $F(h + \triangle h)$ in art. 98, and the subsequent reductions made as in that article, (the transformations the above terms undergo are very easily traced), we find in place of *eq.* (14) that for the most economical height,

$$W_c = w_s \frac{h}{h_1} + w_s' \frac{h}{h_2} + \Sigma w (\cos. 2i + \frac{h^2}{l^2} m)$$

130. In this formula w_c = weight of chord due to variable elements *ati* and $auq = 55733$ lbs. The posts *et*, *ia* and end posts being all 30 diameters long and vertical, $\cos. 2i = 1, \frac{h^2}{l^2} = 1$, $m = \frac{3}{7} + \frac{18}{39}$, and their weight $W_p = 16069 + 17111 = 33180$ lbs.

The weight of ties, *at*, *ti*, . . . , inclined at 56°19 to the vertical is $w_t = 17469$. For them *cos.* $2i = -.385$. The w't. of $au\ uq = w_t{}' = 48765$. For them $\cos. 2i = -.6$. Also $w_s = 4770$ and $w_s{}' = 952$.

Now if the most economical height has been chosen we should have

$$W_c = w_s \frac{h}{h_1} + w_s' \frac{h}{h_2} + W_t \times (-.385)$$
$$+ W_t'(-.6) + W_p (1 + m).$$

Actually we have,

$$W_c = 55732 > 11250 - 35985$$
$$+ 62714 = 37979,$$

The chords being the greater, the depth ($33\frac{1}{3}'$) is too small for theoretical economy; but it would hardly be prudent to increase it.

131. If however we take the pier towers at 27000, the right member equals 57096, which nearly equals W_c.

132. The Fink truss is better adapted for a deck than a through bridge, and possesses one advantage for either form over all others; "compensation" under live loads or changes of temperature; each isosceles triangle or "element" being independent in its action of every other, there can be no loose counters causing distortion of the bridge as in some beam trusses. Its action in practice is said to be "perfect." It would seem that an increase of diameter of the heavy chord of the Fink would benefit it more than a similar operation would benefit the quadrangular trusses. A re-estimate can alone determine.

132. It may be remarked that the number of panels in a Fink is, from the peculiar design, some power of 2; 2, 4, 8, 16, 32, &c., thus fixing a panel's length. The Quadrangular trusses on the contrary can have any number of panels, thus giving it a greater adaptability to various spans. The Triangular truss with suspenders has necessarily an even number of panels. But with some of the center panels built on the quadrangular plan (as has been done), thus giving short posts, where material is most likely to be wasted, the adaptability to any span can be made equal to that of the quadrangular trusses.

For very long and deep spans—300 to 600 feet and upwards—vertical posts throughout would seem to be desirable; for if inclined, the flexure from their own weight would be appreciable and might continually increase besides.

The posts, when the truss is high enough to admit of it, are often braced together between their ends, thus shortening practically their length as compared with their diameters, and adding materially to the stiffness of the system.

133. *Bow String Girder*.—This truss, depicted in Fig. 15, is assumed, as before, to have 200 feet span, divided into 12 panels, and to weigh 336000 lbs. (entire bridge). The center height is assumed at 30 feet. The counters are omitted in Fig. 15, as we shall assume them out of action when the bridge is loaded uniformly, which case will first be investigated.

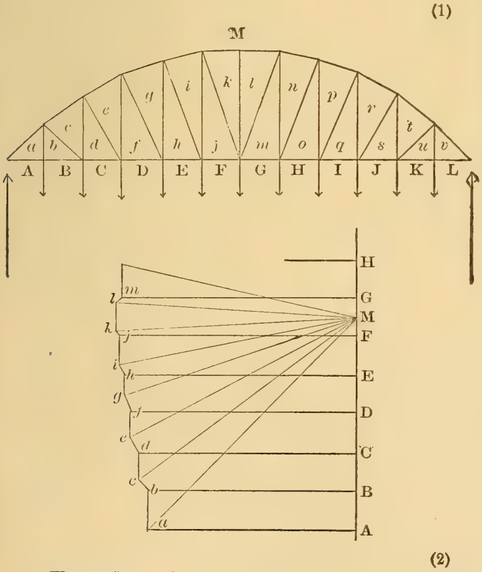
134. Using Bow's ("Economics of

Construction," &c.), notation, we denote any bridge member, in Fig. 15, (1) by the two letters placed either side of it; thus the first vertical on the left is *ab*, the next *cd*, &c. Similarly the first bow piece on the left is *a*M, the next *c*M, &c.; the first chord piece is *a*A, the next *b*B, &c. The same notation applies to the forces AM, AB, BC, &c.

135. Let the bridge be loaded with its own weight only, 14000 lbs. per panel on one truss; *i.e.*, AB=BC=CD=&c.= 14000 lbs. Then the reactions AM and LM are $5\frac{1}{2}\times 14000$.

Lay off, in Fig. 15 (2) the forces AB, BC, &c. vertically, also the reaction AM, and draw the lines, as per figure, whose extremities are marked by any two letters, *parallel* to the members of the truss, Fig. 15 (1), indicated by the same letters; then will the lengths of the lines in (2), measured to the same scale as the forces AB, ... give the strains on the members of the truss (1) indicated by the same letters.

FIG. 15.



Thus M*a*, (2), is drawn parallel to M*a*, (1), and M*a*, (2), measured to scale is the strain on M*a* (1).

Similarly A*a*, *ab*, *bc*, M*c*, &c., in (2) are the strains on the corresponding parts in (1).

136. This results from the well-known law of mechanics, that if a number of forces acting at a point are in equilibrium, then if we lay off the forces in order, "the polygon should close." Also, having given, at any apex, the direction of one force, by following around the corresponding polygon we find the directions of the others. If the force, representing the stress on a member, is thus found to *act away from the apex.*, the member is in tension, *if towards the apex* the member is in compression.

Thus at apex AM*a*, AM is given acting upwards: then in (2) following around the polygon AM*a*A in order, M*a* is found to act *towards*, and *a*A from the apex; *i.e.*, *a*M, (1), is in compression and *a*A, (1) in tension.

Be careful to note now that these same pieces *act* in an opposite direction at their other ends. Thus at apex AB*ab* (1), *a*A acts to the left, *being in tension;* then following around the corresponding force polygon (2) in the order A*ab*BA, we find *ab* and *b*B acting away from the apex, hence in tension. Next at apex M*abc* (1),*a*M*cba* (2) gives CM compression and *bc* tension. Similarly all the web members will be found in tension, the bow in compression and the chord in tension.

We determine first the strains at a chord apex, to find the strain on the vertical, then go to the bow apex above it, where, the strains in *two pieces* only being unknown, can be readily found.

137. The strains were of course determined from a larger drawing, the truss being drawn to a scale of 10 feet= 1 inch, and the force diagram being drawn to a scale of 20000 lbs.=1 inch.

We thus find that the *dead load alone* strains the ties, *bc*, *de*, *fg*, *hi*, *jk*, 4700, 4000, 3300, 2900 and 1300 pounds respectively. The verticals thus carry the greater part of the weights. With engine at the foot of tie *ab*, its maximum strain is 45000 lbs.

It was not considered judicious to proportion the verticals (when acting as ties) for a less strain, as a very slight error in the length of a diagonal could cause the vertical (neglecting the counter, supposed loose however) to sustain the whole panel reaction of 45000 lbs.

138. For a uniform live load, the force diagram is similar to (2), and the bow and chord strains can be most conveniently obtained from it. With the locomotive excess placed so as to give

max. chord strains, a new diagram would be required for every new position of the load however and on that account it is simplest to use the principle of moments.

139. The maximum moment about an apex n panels distant from the abutment is given by the eq., art. 39, by simply dividing by h, as is sufficiently evident.

$$\therefore M_n = \left\{ \frac{Pl}{2}(N-n)+\frac{El}{N}\left(N-\frac{c}{l}-n\right) \right\} n$$

In the case of the Bow String girder, the lever arms for panels Aa, Cd, Df, Eh, Fj respectively are ab, cd, ef, gh and ij respectively. The lever arms for the arch panels Ma, Mc, Me, Mg . . . are the perpendiculars drawn from the apices Ab, Bd, Cf, ... respectively to the chords of the arcs Ma, Mc . . . .

Substituting now in the last eq.,

$$N=12,\ l=\tfrac{50}{3},\ E=60000,\ \frac{c}{l}=1\tfrac{1}{2},\ P=30666$$

we have,

$$M_n=[255550(12-n)+83333(10\tfrac{1}{2}-n)]n$$

whence we find the strains in,

$$Aa=Bb=\frac{M_1}{9.8}=\frac{3602713}{9.8}=367620,$$

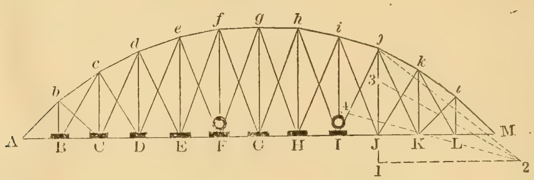
$$Ma=\frac{M_1}{8.43}=427000,$$

$$Cd=\frac{M_2}{17.3}=\frac{6527660}{17.3}=377320,$$

&c., &c., as entered in the table below.

140. *Maximum Web Strains.* The following method of ascertaining the max. web strains is due to Stoney ("Strains in Girders," etc., art. 211). Suppose the truss without weight. Let the live load, engines in front, extend to the foot of the tie whose max. strain is required. Then, in Fig. 16, if we suppose the panel IJ ij cut and forces applied at the cut pieces equal and opposite

FIG. 16.



to the resistances of those pieces the right segment of the truss will be held in equilibrium by the reaction at the right abutment, the horizontal tension in IJ, and the resultant of the strains in Ij and ij. The two former met at M, hence the resultant at j must pass through M.

Therefore, if we draw, by scale, $\overline{ji}$ vertically, and equal to the reaction (which is also the shear over panel IJ), and draw 12 horizontally till it meets jM produced at 2, then $\overline{2j}$ is equal and opposed to the forces supposed *applied* in the directions, ij and jI at j; whence drawing 24 parallel to $\overline{ij}$, $j4$=strain on tie, and 24 on bow ij for this position of the load.

Similarly if we suppose the truss severed through IJjk, $2j$ will be the resultant of the resistances of jJ and jk at j; or, $j2$ acting in the direction from j to 2 is in equilibrium with those resistances. Hence, drawing 23 parallel to jk, on following around the force polygon in the order, $j23j$, we find $3j$=strain on jJ *compression* as it acts *towards j.*

141. From this method of construction we see that the strains on any two web members as Ij and jJ are greater the greater the reaction, provided there is no load on the right segment; hence, omitting the case of the right segment being loaded for the present, the strains on a tie and the vertical connecting with its top, when the greater segment only is loaded are a maximum, when the live load—engines in front—extends from the *farthest abutment* to the foot of the tie. The counters Ji and Kj are supposed loose or out of action, hence were disregarded.

141. We proceed similarly for the other diagonals and verticals. The method is the same for the counters Fg, Ef, ... : the live load extending from their feet to the nearest abutment for their max. strains. Now add, with its proper sign (+ for compression, — for

tension), the effect on the *posts* of the dead load, as found from the construction Fig. 15, to the strains just found, from Fig. 16, *when the live load extends to the farthest abutment.*

Post Fig. 16	Dead Load.	Live Load.	Total Strain.
K*k*	− 11800	+ 13000	+ 1200
J*j*	− 11000	+ 22000	+ 11000
I*i*	− 11200	+ 27500	+ 16300
H*h*	− 11900	+ 31000	+ 19100
G*g*	− 11600	+ 32300	+ 20700

Next, in Fig. 15 (1), conceive the diagonals only in the direction of the counters—they thus suffer compression for a uniform load—and draw the corresponding strain diagram due to dead load only. It is convenient to draw it directly over Fig. 15 (2), as the inclinations of all the pieces (but the diagonals), and also the loads, have been already laid off in proper position. An explanation of the construction for one panel will suffice. Place *b* and *c*, Fig. 15 (1) on either side of the diagonal from A*b* to *ce*, so that the bow piece is M*b* and the chord piece B*c*. Then in Fig. 15 (2) extend *ab* to intersection with M*c*, and draw *cb* ǁ *cb* (1) to intersection with B*b* prolonged; then $ab = -18300$ gives the strain in the first vertical due to dead load. Similarly we proceed for other panels. The strain diagram for Fig. 20, inverted, applies here exactly. The strains in the counters due to dead load are obtained from the same figure.

Since, when the live *load extends to the nearest abutment* the counter connecting with the post is alone in action, we must add the strains on the posts found from Fig. 16, for this case, to the strains just found on the diagonals in the direction of the counters, due to dead load. We thus find,

Posts Fig. 16	Dead Load.	Live Load.	Total Strain.
K*k*	− 17800	+ 16500	− 1300
J*j*	− 17000	+ 23000	+ 6000
I*i*	− 16400	+ 27500	+ 11100
H*h*	− 15300	+ 31000	+ 15700
G*g*	− 14000	+ 32300	+ 18300

On comparing this table with the preceding, we see that, in this example, the posts are most strained when the live load extends from the farthest abutment to the foot of the tie connecting with them. The same is true for the main ties, since they can only take tension. The max. strains thus far found are entered in the following table :

142. We have previously found that for dead load the diagonal web members are only slightly strained. If the counters are tightened too much, it would tend to relieve the main ties of strain, but to increase the strains on the posts. Thus if counter *j*K is in action, say it is strained 10000 lbs., then *j*2 acting from *j* towards 2 is opposed to the the resultant of the resistances J*j*, *j*K and *jk*. Hence extend 23 so that 3 will have such a position that a line drawn from it parallel to counter *j*K to intersection, 5, with *j*J will measure 10000 lbs. The force polygon formed, *j*235*j*, gives as explained before, 23, compression on *jk* (greater than before), 35, tension on counter (10000 lbs.) and 5*j* compression on post J*j*, considerably greater than before.

Hence an ignorant tightening of the counters may easily double or treble the strain on the posts for which they will be designed in what follows.

Another very objectionable feature in this truss, is the fact that for a uniform load there is tension only in the verticals, whereas, when the train is only partially on the bridge, they are each in turn subjected to compression ; changing thus quickly from a possible 45000 lbs. tension to a max. compression of 20000 lbs. (about, for middle posts), or the reverse. The verticals were consequently designed, each to consist of two plates connected by the usual latticing and angle irons of sufficient section to resist both strains, and were of course "hinged at both ends."

143. We thus see that the great saving in the web in this form of truss is really the greatest objection to it, at least for a railway bridge. The bow form is best used in the plate girder.

144. The successive *reactions* at the right abutment in last Fig. are easily found from *eq.* (5), art. 19, by making the dead load, $p=o$. The reactions are the same then as the shears on the right segment. Expressing them in hundred weight, we have

$S_1=1391$, $S_5=664$, $S_9=158$
$S_2=1188$, $S_6=516$, $S_{10}=92$
$S_3=1000$, $S_7=383$, $S_{11}=39$
$S_4=825$, $S_8=264$, $S_{12}=0$

Due regard was paid to the rear engine moving off the bridge by modifying the formula as suggested in art. 19.

145. Combining the max. strains found on the main ties due to live load with those previously given due to dead load (art. 137) the results are entered,

BOW STRING GIRDER—THROUGH BRIDGE.

Piece.	d	$\frac{l}{d}$	th.	Strain.	θ	b	Area.	Len'th	No.	k	Weight.	Totals.
	″		″								lbs.	
Ab	$13\frac{1}{3}$	17.7	$1\frac{7}{16}$	427000	.39	8000	53.4	19.6	4	$\frac{10}{3}$	13955	
bc	"	16.		413140	"	9040	45.7	18.3	"	"	11151	
cd	"	"		404370	"	"	44.7	17.5	"	"	10430	
de	"	"		396330	"	"	43.8	17.1	"	"	9986	
ef	"	"		388780	"	"	43.	16.8	"	"	9632	
fg	"	"	$1\frac{1}{8}$	381660	"	"	42.2	16.7	"	"	9396	64550
*Post Kk	5	$33\frac{1}{3}$	$\frac{1}{2}$	1200	0	3000	0.	17.3	"	"	0	
Jj	7		$\frac{9}{14}$	11000	0	"	3.7	23.	"	"	1135	
Ii	8		$\frac{11}{16}$	16300	0	"	5.4	26.9	"	"	1937	
Hh	9		"	19100	0	"	6.9	29.2	"	"	2492	
Gg	9		"	20700	0	"	6.9	30.	2	"	1380	6944
Latticing, angles, &c. 27 lbs. pr. ft.								111.4	4	"	12032	12032
Lower Chord				2263400	.39	10420	217.2	$\frac{100}{6}$	4	"	48267	48267
Tie Kl				34200	0	7500	4.6	19.3	"	"	1184	
Jk				41000	0	"	5.5	24.	"	"	1760	
Ij				46000	0	"	6.1	28.5	"	"	2318	
Hi				49900	0	"	6.6	31.8	"	"	2798	
Gh				51300	0	"	6.8	33.7	"	"	3055	
Counter Fg				50200	0	"	6.7	34.3	"	"	3064	
Ef				48000	0	"	6.4	33.7	"	"	2876	
De				43200	0	"	5.8	31.8	"	"	2459	
Cd				43100	0	"	5.8	28.5	"	"	2204	
Bc				44200	0	"	5.9	24.2	"	"	1903	
Vertical Ties				45000	.13	8470	5.3	121.2	"	"	8565	32186

* The thickness of metal "th" is made up of that due to the vertical acting as a tie (5.3) + that due to its acting as a strut.

together with the strains on the other members of the bridge in the adjoining table; from which we deduce as before the

BILL OF MATERIALS.

Bow String Through Bridge, 200′ span, 30′ rise.

	lbs.
Bow and posts, with latticing &c.	83526
20 p. c.	16705
Chord ties and counters	80453
15 p. c.	12068
Other items as in art. 47	134100
Total weight of bridge	326852
Assumed weight	336000
	9148

146. We have assumed the same percentages and estimates of loops, transverse bracing &c., as previously given for the Triangular and Whipple bridges, which is only approximately correct.

The bow piece can be more conveniently constructed of some other form than the phoenix column, so that the above estimate is favorable to this form of truss. The principal objection urged to the Bow String Girder is, that the web members are so slightly strained from dead load, that the rolling load may find them out of action, thus giving rise to hurtful vibrations.

The difficulty in cross-bracing the bow is also a great objection to this truss as a through bridge.

147. In the previous investigation of the Bow String Girder, only one system of triangulation was assumed and the

most economical height was not found as for the other trusses examined.

As the web is comparatively light and some of the ties have about their most economical inclination, 45°, it is not probable that a double system of triangulation, for the span and panel length assumed, would involve as much saving as we found in the quadrangular truss.

The height assumed, 30 feet, is slightly greater than for the beam trusses, as it was thought that the light web would admit of a greater height. Trial only can determine the most economical height. It would seem that the change of a foot or so would effect a very slight saving however, if we may judge at all from the previous investigations concerning the beam trusses.

148. *Analytical Formulæ.*

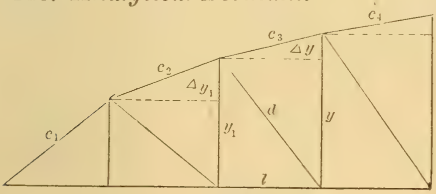


Fig. 17

Let us call the successive lengths of the bow, $c_1, c_2, \ldots$; the length of a post y, the length of the post to left of it y_1; d the length of a diagonal connecting y and y_1; Δy_1=difference between y_1 and the length of the post to the left of it; $\Delta y = y - y_1$. Also the pieces can be designated by the letters next them on the figure above, prefixing the words *post*, *tie* or *piece* to avoid any confusion.

Call the *moment* of the external forces (reactions and loads) on one side of *post* y, about its foot as a center of moments, M_y; similarly for M_{y_1}; also call the *shear* in the panel included by y and y_1, *for the same distribution of the load* S_y.

Designate a panel length by l; the inclinations of pieces $c_1, c_2, \ldots$ by $a_1, a_2, \ldots$ and of the diagonal d by β.

Also denote the strains in c_3, y, d, etc., by the corresponding capital letters, C_3, Y and D.

149. Suppose a vertical section cutting pieces c_3 d and l, and take the intersection of d and l as a center of moments to find the strain C_3, whose lever arm is

thus, $\quad y \cos a_3 = y\dfrac{l}{c_3}$

$$\therefore\ M_y = C_3 y\frac{l}{c_3} \quad \therefore\ C_3 = \frac{M_y}{y}\frac{c_3}{l} \quad \ldots (1)$$

If we supply forces (as in art. 7, Fig. 2) at the supposed vertical section (cutting c_3 d and l) *equal and directly opposed* to the resistances of the cut pieces, we must have the algebraic sum of their vertical components equal to S_y. Compare art. 8. Now since the bow is always in compression—since every weight on the truss causes an upward moment—the external force opposed to the resistance in piece C_3 acts downwards.

$$\therefore\ S_y = D \sin.\beta + C_3 \sin.a_3 = D\frac{y_1}{d} + \frac{M_y}{y}\frac{c_3}{l}\frac{\Delta y}{c_3}$$

$$\therefore\ D = \frac{d}{y_1}\left(S_y - \frac{M_y}{y}\frac{\Delta y}{l}\right) \quad \ldots (2)$$

On the right half of the truss the force opposed to C acts upwards. Since Δy is then minus eq. (2) applies on changing the sign of Δy. Again, note that when S_y is minus it must be so substituted in eq. (2). When D is plus, the diagonal is in tension, otherwise in compression.

The reader will do well to sketch the truss up to the section and the forces acting on it, as in Fig. 2, in this and subsequent articles.

150. Next conceive the section parallel to diagonal d, cutting pieces c_2 y_1 and l; and balance the vertical components of the "acting forces," which include the reaction and loads left of the section, and the supposed forces equal and opposed to the resistances of the cut pieces

$$\therefore\ S_y = Y_1 + C_2 \sin.a_2$$

From eq. (1) we can derive,

$$C_2 \sin.a_2 = \frac{M_{y_1}}{y_1}\frac{c_2}{l}\frac{\Delta y_1}{c_2} = \frac{M_{y_1}}{y_1}\frac{\Delta y_1}{l}$$

Now $M_{y_1} = M_y - S_y\, l$, as may be shown as follows:

Suppose a section cutting y, c_3 and the chord piece to right of piece l; and supply forces equal and opposed to the resistances of the cut pieces. Decompose the applied force $=C_3$, at top of post y, into vertical and horizontal components. The latter component is equal to the force applied at the cut chord piece and forms with it a left-handed couple, equal to M_y, since the moment of the vertical component $+Y=S_y$ is zero; these forces

acting through the center of moments—the foot of post y.

Hence, regarding the left-handed couple ($=M_y$) and the sum of the vertical components ($=S_y$), acting downwards if S_y is +, as the external forces at the section, we have the *moment* about the foot of post y_1, $M_{y_1}=M_y-S_y l$ as was to be proved.

It is useful to note that, since $M_y=M_{y_1}+S_y\,l$, the moment increases in going from y_1 to y, so long as S_y is positive. Therefore at the point where $S_y=0$ the moment is a maximum (compare art. 90).

Substituting the above value for M_{y_1}, we have for the strain in the post y_1

$$Y_1=S_y-\frac{M_y-S_y\,l}{y_1}\,\frac{\triangle y_1}{l}\quad\ldots\;(3)$$

As before, when S_y or $\triangle y_1$ are negative, they must be so substituted in this formula.

151. *The Maximum Strains* on a tie we have previously found to be when the load extends from the foot of the tie to the farthest abutment; for a counter tie, the load extends from its foot to the nearest abutment. Therefore, for maximum strains, the shears S_y are easily obtained from eq. (5), art. 19.

The corresponding moments M_y are found thus: to S_y add the dead load between the post marked y and the left abutment to find the *reaction*, whose moment about y, minus the moment of the downward loads from the abutment to y gives M_y.

152. *Example.* Required the max. strain, D the counter $\overline{iJ}$ ever sustains, for the bow string girder, Fig. 16 previously examined. The live load extends from M to J. By table, art. 21, $S=-19172$. Reaction at $A=-19172+8\times14000=92828$.

$$\therefore\ M_J=92828+150-112000\times75=5{,}524{,}200,$$

whence by eq. (2)

$$D=\frac{31.8}{26.9}\left(-19172+\frac{5524200.3.9\times6}{23\qquad100}\right)=43770.$$

The graphical analysis gave 43200.

153. For a post as $\overline{Ee}$, the live load must either extend from M to F or from A to D to cause max. strains. In the first case the strain on $\overline{Ee}$ is by eq. 3.

$$Y_1=87364-\frac{9613667-87364\frac{100}{6}}{26.9}.\frac{3.9\times6}{100}=16402$$

Secondly, since post $\overline{Ii}$ for live load from M to J sustains the same strain as $\overline{Ee}$, when the load extends from A to D, we have for the strain in this case,

$$Y_1=-19172+\frac{5524200+19172\frac{100}{6}}{26.9}.\frac{2.3\times6}{100}=10808$$

The graphical analysis gave 16,300 and 11,100 respectively. In this way we can form the following table; where column 1 gives the post, columns 2 and 3 the strains sustained by it, when the live load extends from the foot of the tie or counter connecting with it to the farthest or nearest abutments respectively:

Cc	1600 comp'n	182 tension
Dd	9318 "	6200 comp'n
Ee	16402 "	10808 "
Ff	19008 "	17150 "
Gg	18470 "	18470 "

In this case, we see that the posts are most strained when the live load extends to the farthest abutment. The strains found by the preceding formulae were found to differ from those found by construction less than 1000 lbs. as a mean, the extreme difference being 3000 lbs. This is due partly to the short lengths of the bridge members from which their inclinations were derived, and partly from the unavoidable errors of construction, as well as from the dimensions being taken to only tenths of a foot in the formulae. Other formulae could be given but we have preferred those of Schwedler on account of their compactness and as introductory to his bridge.

154. *The Schwedler Bridge.*—In this bridge, the upper chord is parallel to the lower chord in those panels where counters would be required in a Pratt or a Howe truss; *e.g.*, for the four middle panels, for the span, panel length and loads previously considered. In the other panels, the height of post is so regulated that no counters are required; *ie.*, the diagonals act as ties only or as struts only.

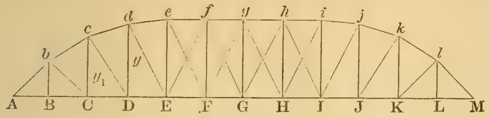


Fig. 18

Now the max. reverse strain, in a diagonal as $\overline{Dc}$ (Fig. 18), is when the front engine is at C and the load extends to A. The condition for this truss is, that this strain must be zero for those panels where no counters are to be used. Placing *eq.* (2) equal to zero, we deduce, for the left half of the truss,

$$\triangle y = y\frac{S_y\,l}{M_y} \;\ldots\ldots\ldots (4)$$

In this formula, it is understood that the front engine is at the post marked y_1, and the live load extends to the left abutment, the moment M_y being taken about the post y.

155. *Example.*—Take the span=′200, $l=\frac{100}{6}$, loads &c. as before. Assume $Ee=30'=y$.

With engine at D and load extending to A, the moment about E is

$$M_y=5,844,000 \qquad S_y=-19172$$

$$\therefore \triangle y=-30\frac{19172\times\frac{100}{6}}{5844000}=-1.6$$

$$\therefore Dd=30-1.6=28.4 \text{ feet.}$$

Again, write $y=28.4$, with load from A to C, $M_y=4,525,000$ and $S_y=-39836$, whence by (4) $\triangle y=-4.1$ $\therefore$ $\overline{Cc}=24.3$ finally put $y=24.3$, $S=-59112$, with live load at B only, the moment about $C=M_y=2,981,000$ $\therefore$ $\triangle y=-8$, whence $Bb=24.3-8=16.3$.

156. Should more concentrated loads *ever* be allowed to pass over the bridge, the posts should be increased in length for them, otherwise the destruction of the bridge is inevitable. It should therefore be proportioned for a greater load than can ever by any possibility come on it, which would somewhat lessen the economy shown below.

157. The max. strains on ties and posts are found by using eqs. (2) and (3) as previously explained, the load extending to the farthest abutment for the posts.

The minimum strain on the first and last three diagonals is zero, for this truss; the same is true for the posts at their feet, since the vertical strain is transmitted to one by the other entirely.

158. The computation of some of the web members will now be given.

Max. strain in $\overline{bC}$ is when engine is at C and load extends to M. In eq (2) write $d=\overline{bc}=23.3$, $y_1=\overline{Bb}=16.3$, $y=\overline{Cc}=24.3$, $\triangle y=8$ &c., whence max. strain in

$$bC=\frac{23.3}{16.3}\left(181840-\frac{6294667}{24.3}\,\frac{8}{\frac{100}{6}}\right)=82,131$$

$\triangle y$, $\triangle y_1$ become zero for some of the center panels, reducing the case to that of the Pratt truss.

From eq. 3 the max. strain in post $\overline{Cc}$, (load from M to D) is,

$$148960-\frac{8,148,000-148960\frac{100}{6}}{24.3}\,\frac{8\times 6}{100}$$
$$=37060.$$

159. The chord strains are determined as explained for the Bow String. The lever arms of C_2, C_3, C_4, as determined from a drawing, are 21.9, 27.6, 29.9 respectively.

160. The results for the Schwedler truss of 200′ span 30′ center height, &c., are entered in the following table:

(*See Table on following page.*)

Bill of Materials.

Schwedler Bridge, (through) 200′ span 30′ high.

	lbs.
U. chord and posts...........	78,574
20 p. c.........................	15,714
Ties and lower chord.........	65,801
15 p. c.........................	9,870
Other items as in art. 47.......	134,100
Total weight of bridge...	304,059
Assumed weight.	336,000
	31,941

161. Collecting together the estimates of weights of the *through* bridges examined, arts., 108, 128, 145 and 160, we have, in round numbers,

Weight of	Triangular	Truss,	325000	lbs.
"	" Whipple	"	325000	"
"	" Pratt	"	333000	"
"	" Fink	"	356000	"
"	" Bow String	"	327000	"
"	" Schwedler	"	304000	"

The pier towers of the Fink were put at 27000 lbs. These weights will differ still more on a re-estimate, on assuming dead loads more in accordance with the truth.

SCHWEDLER THROUGH BRIDGE—TABLE OF WEIGHTS.

Piece.	d.	$\frac{l}{d}$	th	Strain.	θ.	b.	Area.	Length.	No.	k.	Weight.	Totals.
	"		"				□"	'			lbs.	
*Bow C_1.....	$13\frac{1}{3}$	21		308910	.39	7650	40.4	23.3	4	$\frac{10}{3}$	12551	
C_2.....	"	16	$\frac{13}{16}$	298060	"	9040	32.9	18.5	"	"	8115	
C_3.....	"	"		317930	"	"	35.2	17.2	"	"	8072	
C_4.....	"	"		345960	"	"	38.3	16.7	"	"	8528	
C_5.....	"	"		374530	"	"	41.4	$\frac{100}{6}$	"	"	9200	
C_6.....	"	"		381660	"	"	42.2	"	"	"	9378	55844
*Post *Cc*.....	$9\frac{5}{8}$	30	$\frac{5}{16}$	37060	0	3930	9.4	24.3	"	"	3045	
Dd.....		"	$\frac{3}{8}$	54466	0	"	13.8	28.4	"	"	5225	
Ee.....	12	"	$\frac{7}{16}$	61260	0	"	15.6	30	"	"	6240	
Ff.....	12	"	"	58648	0	"	15.	30	"	"	6000	
Gg.....	9	40	"	31320	0	2810	11.1	30	2	"	2220	22730
Tie *Bb*.......				45000	.13	8470	5.3	16.3	4	"	1152	
Cb.......				82131	0	7500	11.	23.3	"	"	3417	
Dc.......				94830	0	"	12.6	29.4	"	"	4939	
Ed.......				101860	0	"	13.6	32.9	"	"	5965	
Fe.......				99886	0	"	13.3	34.3	"	"	6082	
Gf.......				67054	0	"	8.9	"	"	"	4070	
Counter *Hg*...				35809	0	"	4.8	"	"	"	2195	
Ih...				6151	0	"	2.	"	"	"	915	28735
Chord AC....				221020	.39	10420	21.2	$\frac{100}{3}$	"	"	9422	
CD....				268630	"	"	25.8	$\frac{100}{6}$	"	"	5733	
DE....				308970	"	"	29.6	"	"	"	6578	
EF....				344808	"	"	33.1	"	"	"	7355	
FG....				374530	"	"	35.9	"	"	"	7978	37066

* The compression members are regarded as Phœnix columns in the computation, though other forms may be more convenient in construction. C_1 was taken as "hinged at one end," the other chord panels as "flat at both ends," the posts as "hinged at both ends."

The superiority of the Schwedler Truss in point of weight is marked, and should receive careful attention from constructors.

162. Several other through trusses were examined, as the Lenticular or Fish-bellied Girder, and the Triangular, with two suspenders to a panel, instead of one; but little or no economy was found over the Whipple Truss above. The truss figured in VAN NOSTRAND'S MAGAZINE, for November, 1877, p. 461 (Fig. 8), on data above, weighs 320,000 lbs.

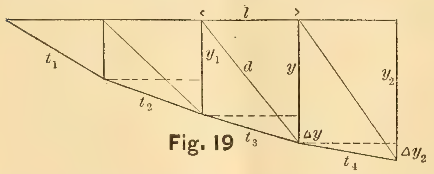


Fig. 19

163. BOW STRING DECK BRIDGE.—*Formulae.*—Call the bow pieces $t_1, t_2 \ldots$; the length of the post to the right of y, y_2; put $y_2 - y = \Delta y_2$; the other notation as before.

The strain in piece t_4 is, $T_4 = \frac{M_y}{y}\frac{t_4}{l}$ ..... (5), since the lever arm of piece t_4 about the top of post $y = y\frac{l}{t_4}$.

164. Now conceive a vertical section cutting pieces l, d and t_3, and balance the vertical components.

$$\therefore S_y = D\frac{y}{d} + T_3\frac{\Delta y}{t_3} = D\frac{y}{d} + \frac{M_y - S_y l}{y_1}\cdot\frac{t_3}{l}\cdot\frac{\Delta y}{t_3}$$

$$\therefore D = S_y\frac{d}{y} + S_y\frac{d}{y}\frac{\Delta y}{y_1} - \frac{dM_y}{y_1 y}\frac{\Delta y}{l}$$

$$\therefore D = \frac{d}{y}\left(S_y - \frac{M_y}{y}\frac{\Delta y}{l}\right) \text{ ..... (6)}$$

To the right of the center, Δy is minus, whence the $-$ sign in the( ) is changed to $+$ as is evidently correct.

165. Next conceive a section parallel to piece d, cutting pieces l, y and t_4, and balance the vertical components of the

forces opposed to the resistances of the cut pieces with S_y we find,

$$Y=S_y-T_4\frac{\triangle y_2}{t_4}=S_y-\frac{M_y}{y}\frac{\triangle y_2}{l}\ldots\ldots(7)$$

The same formula applies to the right of the center, since $\triangle y_2$ is then minus and the eq. becomes

$$Y=S_y+\frac{M_y}{y}\frac{\triangle y_2}{l}, \text{ where } \triangle y_2=y-y_2$$

When S_y is minus it must be so regarded in the previous equations.

As the application of the formulae is essentially as just explained for the through bridge it is needless to give it.

166. As it was of special importance to ascertain whether the posts were most strained by the live load extending to the farthest or nearest abutment from the posts considered, for the loads &c. as previously given, the following strains were tabulated referring to the next figure:

Post.	Live Load from Post to farthest abt.	Live Load from Post to nearest abt.
ab	50718	60655
cd	57400	60584
ef	66060	62970
gh	70108	68450
ij	71564	71750
kl	73632	73632

from which we ascertain that *in this case* $\overline{ab}$ and $\overline{cd}$ are most strained when the live load extends to the nearest abutment; for the other posts it extends to the farthest abutment.

167. In this deck truss the constructive difficulty of the joints of the bow is not experienced as the bow is not in tension. The web is heavier and the posts may be made of phoenix columns, with *square* joints at their connections with the chord. These vertical members now bear but one kind of strain; altogether the truss is a good one, and is worthy of more consideration than it has received, as it will be found to be the most economical in weight of any of the deck bridges examined.

168. *Graphical Analysis*—The next figure gives the form of the truss, omitting the counter ties, and the strain diagram for the uniform dead load of 14000 lbs. per panel; which, using Bow's admirable notation, needs no further explanation. From the strain diagram we find the dead load strains on ties, *bc*, *de*, *fg*, *hi*, *jk*, respectively, to be, in round numbers, 6000, 5000, 4000, 3000 and 2000 lbs; the strains on the posts vary from 18000 on *ab* to 14000 lbs. on *kl*.

169. If the members of the *bow* in any bow string truss are given such inclinations that the strains on the web ties are zero, *i. e.* that in the strain diagram *b* and *c* coincide, as well as *d* and *e*, *f* and *g* &c., then the apices of the bow are points in a parabola. For in the *strain diagram* the points *a, b, c, d, e*, ... will all lie in the vertical through *a*, and then since $ab=bd=dg$ . . . . , the *difference* between the *tangents* of the inclinations to the horizontal of any two consecutive bow pieces is the same. For regarding momentarily A*a* as unity, $ab=bd=dg$ $=$ . . . . is the tangent difference in question. This is a property of the parabola Thus assume its equation $y^2=mx$; give x the increment h and call the corresponding increment of y, k $\therefore (y\times k)^2=m\,(x\times h)$. Whence, expanding and taking the difference between the two equations, $2\,yk+k^2=mh$

$$\therefore\frac{h}{k}=\frac{1}{m}(2y+k)$$

Now $\frac{h}{h}$=tangent of the angle made by a chord of the parabola with the axis of y. (In the figure of the truss a horizontal drawn through the point M*jm* (the origin) may be taken as the axis of Y, the line *kl* as the axis of X).

Now giving to y the successive values o, k, $2k$, $3k$ . . . . we find for $\frac{h}{k}$ the successive values,

$$\frac{1}{m}k,\ \frac{1}{m}3k,\ \frac{1}{m}\ 5k,\ \frac{1}{m}7k,\ldots.$$

whose difference is $\frac{1}{m}2k$, *a constant*, which was to be demonstrated.

In the figure of the truss k may be regarded as equal to a panel length $16\frac{2}{3}$ feet, whence h will be the vertical distance between the extremities of the bow piece, the tangent of whose inclination to the horizontal is given by the value of $\frac{h}{k}$, corresponding to the value of y for the lower end of the bow member.

When a parabolic bow string is loaded uniformly the strain throughout the string is uniform, since, in the strain diagram *a, b, c, d* . . . are in the same vertical.

170. As before, to find the max. strains due to live load only on tie 14, we suppose the front engine at IJ and the train extending to the farthest abutment. Lay off the reaction at LM from 1 to 2, and draw 23 parallel to chord to intersection with 13 passing through LM. Then 13 =resultant of reaction and strain in chord panel J, must be in equilibrium

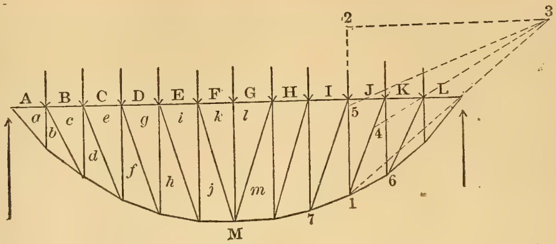
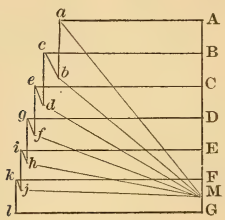


FIG. 20.



with strains in tie 14 and 16; hence drawing 34 parallel to 16, 14=strain on tie due to live load.

Similarly, drawing 35 parallel to 17, 15=strain on post 15 *due to this position of the load;* but we shall find that the posts are most strained *from the live load alone* when it extends from the *nearest* abutment to the post considered; which strains as well as the strains on the counters are determined in a similar manner to the above. Now add the post strains due to live load—extending to farthest abutment—to dead load strains obtained from diagram above, and compare these totals with those found, by adding the post strains due to live load —extending from post to nearest abutment to those found (from a diagram similar to Fig. 15 (1) and (2) inverted), due to dead load, from a figure where diagonals in the direction of counters are alone represented.

We reach the conclusion of art., 166.

From the last mentioned diagram, the dead load strains on counters are found.

171. The total strain on any post cannot be less than 45000 lbs., (the panel reaction), when the engine is directly over it; and proceeding as above we find that the strain on the posts due to live and dead load is not in any case less than 45000 lbs.

Suppose that the loads are so placed that AB has, say, double its value given in the figure, the reaction MA remaining the same; then in the strain diagram for *a*B, *ba* AC*c'b* (*c'* being in the prolongation of *bc* at its intersection with C*e*) we see that *bc* must now act as a strut; *otherwise ab* takes the whole load (2 AB) and a counter must be introduced from its foot to *c*C.

It follows that, for the assumed truss, the counters next an engine *may* be in action when the whole bridge is loaded.

172. *The maximum chord strains* are, for panels $\overline{Aa, Bc, Ce}$, ... respectively, $\frac{M_1}{9.8}, \frac{M_2}{17.3}, \frac{M_3}{23}$ . . . .; the lever arms being respectively $\overline{ab, cd, ef}$, ...

For the Bow we ascertain the lever arms as follows: conceive the panel as M*dec* cut, take the intersection of the tie and upper chord panel *c*C as a center of moments, and from it draw a perpendicular to M*d* produced, which is thus the lever arm of the strain in M*d*. In this case M_2 divided by this lever arm is the strain in M*d*, M_2 being the maximum moment when *c*C is taken as the center of moments.

The max. moment for both M*a* and M*b* is M_1; hence M_1 divided by the length of perpendiculars from *a*B to M*a* and M*b* respectively give the strains in M*a* and M*b* respectively.

Similarly for other divisions of the bow.

173. The strains are entered in the following table. For the posts, θ was taken at .25 as an average, from which none of them differ much. For the ties

BOW STRING GIRDER—DECK TRUSS.

Piece.	d.	$\frac{l}{d}$	th.	Strain.	θ.	b.	Area.	Length.	No.	k.	Weight.	Totals.
	″		″									
Chord, c_1.....	$13\frac{1}{3}$	15	$1\frac{1}{12}$	367620	.39	9050	40.6	$\frac{100}{6}$	4	$\frac{10}{3}$	9022	
c_2......c_6.....	"	"		1909820	"	9270	206.	"	"	"	45778	54800
Post *ab*........	8	"	$\frac{5}{16}$	59000	.25	8140	7.2	9.8	"	"	941	
cd........	8	26	$\frac{7}{16}$	60800	"	5950	10.2	17.3	"	"	2353	
ef........	10	27.6	$\frac{6}{16}$	66000	"	5830	11.3	23.	"	"	3466	
gh........	$10\frac{13}{16}$	30.	$\frac{7}{16}$	71400	"	5290	13.5	26.9	"	"	4842	
ij........	$11\frac{5}{8}$	30.	$\frac{3}{8}$	73900	"	5290	14.	29.2	"	"	5451	
kl........	12	30.	$\frac{3}{8}$	73600	"	5290	14.	30.	2	"	2800	19853
t_1............				426860	.39	10420	41.	19 6	4	"	10715	
t_2............				407550	"	"	39.1	18.3	"	"	9543	
t_3............				400470	"	"	38.4	17.5	"	"	8960	
t_4............				395270	"	"	37.9	17.1	"	"	8641	
t_5............				390350	"	"	37.4	16.8	"	"	8377	
t_6............				387440	"	"	37.1	16.7	"	"	8258	54494
Tie *bc*........				45000	0	7500	6.	24.2	"	"	1936	
de........				50000	0	"	6.7	28.5	"	"	2546	
fg........				52000	0	"	6.9	31.8	"	"	2925	
hi........				54000	0	"	7.2	33.7	"	"	3235	
jk........				54000	0	"	7.2	34.3	"	"	3293	
Counter 1.....				49500	0	"	6.6	33.7	"	"	2966	
2.....				45200	0	"	6.	31 8	"	"	2544	
3.....				39800	0	"	5.3	28.5	"	"	2013	
4.....				37000	0	"	4.9	24.	"	"	1568	
5.....				35300	0	"	4.7	19.3	"	"	1209	24235

θ is put at *o*. The maximum chord strains are $Aa=367620$, $Bc=377320$, $Ce=381510$, $Dg=384540$, $Ei=384790$, $Fk=381660$; the sum of the last five being 1,909,820, as entered in the table. The total weight found is the same whether these chord panels are considered separately or collectively, the length being the same for each piece.

BILL OF MATERIALS.

Bow String Deck Truss, 200′ span, 30′ center depth.

	lbs.
U. chord..........................	54800
Posts.............................	19853
20 p. c. on two last............	14930
Bow............	54494
Ties..............................	24235
15 p. c. on two last............	11809
Other items (art. 91)...........	127230
Total weight..............	307351
Assumed weight..........	336000
	28,649

174. The *Triangular*, Fig. 7 as a Deck Truss, can be best compared with the Whipple, etc., with vertical end posts. However, let us assume the abutments built up to grade to compare with the deck trusses examined. The max. strains are identical with those for the through bridge, except that the vertical posts must now sustain a max. load of about 45000 lbs. The suspenders may be made of one square inch cross section. Estimating as usual we find its weight as given below:

175. *Comparison of Deck Bridges of 200′ span*, loads, etc., as previously given.

Triangular,	28′	high,	321,000 lbs.
Whipple,	"	"	326,000 "
Fink,	$33\frac{1}{3}$	"	317,000 "
Bow String,	30	"	307,000 "

The Schwedler as a Deck Truss would doubtless prove lighter than any of the previous trusses.

176. With other details than those assumed—and our best bridge companies have devised some excellent ones—the results found may be slightly varied; but it is believed that the general comparisons are correct for any given details. At any rate the data is all given so that

errors can be detected or modifications of design readily made.

177. Although the loads previously assumed are for railroad bridges, yet the formulae, or methods given, can be easily adapted to highway bridges, where the live load is usually taken as so much per square foot of roadway, varying from 35 to 100 lbs. per square foot.

178. A matter of great interest to engineers is the determination of good formulae for compression members. Government aid is anxiously looked for in this direction to institute the proper experiments. Various formulae for different cross-sections are being introduced in some specifications, though they are founded on comparatively few experiments, and thus are only provisional, as indeed are the formulae previously used in this paper for unit strains; but the deduction of Wöhler that a piece will bear a smaller maximum strain the greater the extremes of strain to which it is subjected is not provisional, but a fixed fact, which must be regarded if a bridge is to be designed scientifically; and it is to be hoped that the above will show that there is no difficulty in the application of Launhardt's formula founded on this law.

179. It is believed that there will be no difficulty in applying the preceding principles to any form of truss in ascertaining the greatest or least strain that any member is ever called on to bear. If the truss is composed of two or more web systems, not connected at their intersections, estimate the influence of each separately and combine the effects for a piece that is common to the two or more systems. All the principles relating to the method of ascertaining max. and min. strains, etc., that pertain to a simple system apply to each web system in turn.

UNIFORMITY IN SANITARY ENGINEERING.

From "The Engineer."

We admit that there are exceptions to every rule, and that it is impossible to lay down a hard and fast line, to be adhered to undeviatingly in any branch of the profession. Nevertheless the greater the number of instances to which a general rule can be made applicable, the less troublesome, and what is infinitely more important, the more certain becomes the task of the engineer. By the phrase "less troublesome" we do not mean to imply that the work of an engineer, in a sanitary or other point of view, is to be devoid of trouble and anxiety, but simply that he is fairly entitled to be relieved from any amount of trouble which is, in reality, incurred merely for trouble's sake. Under the latter category may be included unnecessary, and frequently useless routine work, and the planning and execution of schemes which in some cases are nothing better than crude experiments, undertaken to meet contingencies which might readily be provided for by existing arrangements enforced by a proper head or central administration. We are not now about to advocate the creation of a chief or central sanitary authority for large districts, although it may be a matter for consideration whether the important object included in the title of our present articles might not be greatly promoted by the establishment of such an authority.

It cannot fail to strike anyone who is acquainted with the various drainage and sewerage systems prevailing in different towns, that some must possess advantages over others, advantages which are general, and not peculiar to the town or district to which they pertain. It is just possible that there may not be any two towns or districts placed under precisely identical conditions of either nature or art, but there are undoubtedly a large number which are to all intents and purposes, practically so located. To all these, therefore, one and the same uniform system of drainage and sewerage might be applied provided only that a selection could be made of the system presenting the best general advantages. Considerable latitude must be allowed, and great discre-

tion used in determining such a selection. Hitherto in some instances so-called compulsory injunctions have been made, and pretended fines imposed, when compliance with the demands of the authorities was utterly impossible. The case of Kingston-on-Thames, which occurred some two years ago, was of this character, in which the penalties incurred, for non-compliance with the injunction granted to the Thames Board of Conservancy, amounted to the equally decisive and preposterous sum of £10,000. It is needless to add that the penalties were never paid, but it is certainly not creditable to our sanitary legislation that such penalty should either have been incurred by the one party, or inflicted by the other. The carelessness and indifference of the former in incurring it is equalled only by the folly and impotency of the latter in inflicting it.

The statistics of large towns prove that no one system for the disposal of sewage can be rendered universally applicable; but they do not prove that the same rule, of necessity, applies to the collection and removal of it from human habitations. With respect to the latter, if we choose to beg the question, the one universal system would be found in that of water-carriage, which unquestionably conveys the sewage from the vicinity of dwelling-places in the quickest, the cleanest, and in the manner the least offensive to our English habits and prejudices. It is worth noting that, at the conference on the health and sewage of towns held last year, it was one of the "resolutions" arrived at, that, "for use within the house no system has been found in practice to take the place of the water-closet." If this is the case, it could tend very much to the desired uniformity in sanitary engineering if that system of collection and removal were rendered compulsory in all instances where good cause could not be shown against it. This would be the more advantageous, inasmuch as there is only one method or plan upon which the wet or water carriage system can be applied, whereas there are several methods by which the dry system can be brought into operation. Of those different methods it is not easy to determine which is the best. It would appear that recent experiments demonstrated that of them all—and they are all more or less offensive—the pail system is perhaps the least objectionable, especially in large towns. Upon whatever plan the dry system may be carried out its efficient working depends entirely upon the way it is managed. It possesses none of the automatic advantages of removal belonging to the water carriage principle. The contents of privies, ashpits, middens, cesspools, tubs and pails, must be removed by manual labor and transported to their destination along the streets and public thoroughfares. The pneumatic plan, which is adopted in some of the towns of Holland, is an exception to the latter statements or, rather, it would be, were it a genuine dry system. But the pneumatic system deals with a certain quantity of liquid as well as solid sewage. It is, moreover, both complicated and expensive in construction and working arrangements, easily deranged and put out of order, and troublesome and difficult to repair. One of our first sanitary engineers has remarked on this plan that he did not "know one English town in which the apparatus, if adopted, would be other than a costly toy."

To return to the suggestion made at the commencement of our article, with relation to the establishment of large central sanitary authorities or boards, it is obvious that had such authorities existed during the "precipitating mania," happily now over, it is not too much to assert that enormous sums of money would have been saved by both willing victims and unwilling ratepapers. It might be well asked, of what use are Government Commissions, whose labors are carried on at the expense of the community, if the results they arrive at are to be permitted to be totally ignored, and processes which they unanimously and unequivocally condemn are allowed to be put into practical operation, at the cost of those who, however reluctant to pay, are powerless to prevent the imposition of the tax. Assuming that the centralization of sanitary administration were an advisable proceeding, the first difficulty to be surmounted would consist in the selection of a standard or unit of area over which any central authority should have sole jurisdiction. It is absolutely necessary that the unit should be large, in order that some

uniformity at least should result from the administration, and a termination be put to the evils which attend the present condition of affairs in which every "sewer authority," no matter how small may be the field of its operations, can do what seems best in its own eyes. Were the results of bad and defective sanitary arrangements to be confined to the particular district or locality in which they originated, the matter might be left in the hands of the sewer authority of that district to be dealt with. But this is frequently not the case. At present, owing to the want of boards of conservancy, rivers and streams which are preserved from pollution along certain portions of their course, are not so preserved in others. It is becoming every day more and more apparent that we shall be compelled to increase the scale upon which the sanitary engineering of the country is conducted. The water supply—the most important feature in the whole of sanitary administration—of many of our large towns is lamentably deficient in both quantity and quality. The fact is that the original sources of supply are no longer adequate to meet the ever-increasing demands made upon them. The Thirlmere scheme as a new source for the supply of water to Manchester is a case in point. It may be remarked here that there are comparatively few water-closets in Manchester. They are discouraged as much as possible by the local authorities, who practically restrict the use of them to houses of the better class. If Manchester had been drained and sewered similarly to London, on the water carriage principle, it would have required a better supply of water long before the present time.

It has been proposed that the unit of area referred to should comprise a county, and we do not think this would be found in any degree excessive. There is a good deal to be said on both sides of the question, but there is no doubt that the establishment of central or district boards would tend to the reformation of our present sanitary legislation. They would do away with a number of inferior local boards and officials, professional and otherwise of very limited qualifications and attainments, and, in their stead, substitute uniformity, efficiency, and economy. There is one point which deserves the serious consideration of the present Local Government Board, or any future head or central sanitary authority. It is the position of the engineer and surveyors to local boards. The tenure of their office depends upon the will, and frequently the caprice of their respective boards. It ought to be similar to that of the medical officer, who has the right to appeal to the chief authority in case of dismissal by the board.

A HISTORY OF DEEP BORING, OR EARTH BORING, AS PRACTISED ON THE CONTINENT.

By Mr. J. CLARK JEFFERSON, A. R. S. M.

A Paper read before the Midland Institute of Mining Engineers.

The writer observed that in bringing under the notice of the members of the Institute a short history of deep boring, or earth boring, which has been, and was still, carried on on the Continent, he believed he should be able to point out many inventions and arrangements which were quite new, and not unworthy of the attention of most of the members. The outcrop of the coal measures in this country, the comparatively small depth and level character of the coal seams, has hitherto not made such great claims on the art of boring as on the Continent, where lying mostly under newer formations and at great inclinations, necessitated deep borings previous to the commencement of sinking operations. Lately, however, in this country they had witnessed the searching for coal under formations newer than containing the coal measures. The Wealden borings in Sussex were, perhaps, the most notable examples. The fact of part of

the Nottingham coal-fields dipping eastward naturally led to the question —whether there would not be some probability of finding coal in the center of Lincolnshire if borings were carried on sufficiently deep. Indeed, the deeper the coal seams lie, the greater will be the need of careful boring to ascertain their depth and character, and it might be that at some future date it would be the lot of some of the members of that Institute to search in a more easterly direction for fresh deposits to supply the exhaustion of seams in the center of the coal measures in West and South Yorkshire. Although he should endeavour to deal with the subject as much as possible in an historical manner, he should consider it under the following heads:

First, the borer or boring apparatus;

And Second, the surface arrangements, and, lastly, the removal of the hindrances occurring during boring, including the lining of bore holes. The first mention of the art of boring was in a book published by Mr. C. T. Delius, in Vienna in 1770, in which they had only the mere mention of earth-boring. It was pretty generally stated that the art of boring was invented by the Chinese, and was introduced from China into Europe by Jobard. Boring may be carried on in two ways, either with the use of rigid rods or with a rope. Until the invention of the diamond rock drill, boring seldom took place in the popular sense of the term, except for small depths of soft strata. The writer went on to point out at great lengths the various methods of boring, together with the apparatus used on the Continent. He remarked that the process of boring as usually carried on consisted of essentially two distinct portions. First, for raising and the letting fall of some heavy tool into the bottom of the bore hole cutting up and breaking the rock into small pieces; and, secondly, in raising the *débris* or sludge from the bottom of the bore hole. Mr. Jefferson went on to point out that the rope and windlass which were first known and used on the Continent are essentially the same as those used in this country. The use of the boring lever is not, however, so common in this country as on the Continent, where all deep borings are generally carried on by its aid. In speaking of the bore or boring apparatus, including the shaft rods, which were sometimes made of iron and sometimes of wood, he said their breakage, especially at the screw joints, was a thing of constant occurrence in deep holes. Rigidity and lightness being required, the use of wooden rods was frequently adopted, they being found to answer much better when the bore hole is full of water. As far back as the 17th century wooden rods had doubtless been used in Russia and Germany. In 1840 Herr Kind invented the lengthening screw which has entirely superseded the use of the chain in deep borings. The arrangements consist of two long side links which are held together at the top by a sort of pin, the nuts screwing on at the ends outside the links. In the year 1831 borings were comenced at Neusalswerk, in Westphalia, for salt, Herr B. Von Ocynhausin being director of the trials. In 1834 when a depth of 900 feet had been reached, obstacles proved to be insurmountable, although 1300 feet more were required to reach the deposits. Whilst things were in that state it occurred to Von Ocynhausin that if he could detach the lower part of the rods—at least, so much as was necessary for an effective blow—he might overcome the obstacles. The result of such a thoughtful and rational consideration was the invention of a very remarkable instrument, known as the sliding shears, or jaws. Kind's free falling borer, which formed an important continental invention in the art fo boring, was employed for the first time by Herr G. C. Kind, in 1844, in boring at Mondorf, on the boundary between France and Luxemburgh. The writer then proceeded to explain that the free falling instrument is composed of two principal parts—viz., the free falling rod and shears. The free falling rod is provided at the upper extremity with a small tongue piece about 2 inches long $1\frac{1}{2}$ inches wide, and $1\frac{3}{4}$ inches broad, the bottom part of the rod being $\frac{3}{4}$ inch broad, and $1\frac{1}{2}$ inches wide immediately below the tongue. About 12 inches lower down two nose pins of steel are inserted, the bottom of the falling rod terminating on a cylindrical portion or neck, to which the lower rods of the boring chisel can be secured.

RAPID METHODS OF LAYING OUT GEARING.

By S. W. ROBINSON, Prof. of Mech. Eng., Ohio State University, formerly of Illinois Industrial University.

Written for VAN NOSTRAND'S MAGAZINE.

GEAR teeth, more than any other mechanical product, seem destined to suffer for want of correct construction. Advantage seems to be taken of the fact that errors in their peculiar form are not so easily detected as in bodies of more simple shape. No one would dare to leave a hole in a link-rod three-cornered when it is to work on a cylindrical pin. Such a botch would, however, be much less discoverable in its working than errors in gear teeth. In spite of the tale, told loud and long about every such error, makers will still persist in assuming the forms of teeth by guess, because it saves trouble.

There is probably no better way of stopping this abominable practice than by introducing simple and easy methods of laying out the teeth. To point out a few such methods is the leading object of this paper.

The circle arc has been tried as a substitute for the correct, though much more complex curve, the epicycloid, and with results greatly superior to guess curves. But if a curvilinear ruler could be found more approximative to the required curve than the circle, and presenting no greater difficulties in use; it, of course, would be preferable. Such a curved ruler we have in the Templet Odontograph, described at length in this Magazine of July, 1876. The methods of setting there given were intentionally made as free from drawing, and use of instruments, as possible. But the accompanying tables often required interpolations to be made, a thing which most practical men have more difficulty with than with drawing.

But the methods of setting now to be considered are entirely independent of tables and mathematical work, and depend solely upon simple diagrams. The advantage of the latter is very considerable in that the eye is able to detect any error by a glance at the diagram, while the former is accompanied by no such check. A convenient check is sometimes more valuable than a process.

To state briefly in words the general method of procedure to obtain the settings, it is simply to find the radius of curvature of the desired tooth curves, place the templet odontograph on that radius, and strike the tooth curve.

The odontograph is especially adapted for this, in that all the tangents drawn to the curve of the hollow edge of the instrument are normals and radii of curvature to the convex edge. Thus FD, Fig. 4, page 5 of July No., 1876, VAN NOSTRAND'S MAGAZINE, is perpendicular to the convex edge at D, and also FD is the radius of curvature of the curve ADB at D. For this reason the odontograph may unhesitatingly be used instead of a circle for drawing a tooth curve, the proper tangent FD being brought to the circle radius; that radius being so located by construction that the point D will fall in the midst of the arc to be used. This point, for a face of a tooth, may be at about a third of the height. But, to indicate the mode of proceedure more fully, it will be desirable to take up special cases.

I. FOR APPROXIMATING TO EPICYCLOIDAL TEETH WITH CURVED FLANKS.

1st. *For ordinary Spur Gearing.*—In Fig. 1 let A and B represent a pair of pitch circles touching at C; and with ACB the line of centers. To find a face for A, and its properly mated flank belonging to B; draw any circle CD HI, with CH less than the pitch circle radius BC. Then draw a circle through D with the center at A, this circle being about one-third the height from the pitch line of A to the point of a tooth of A. From D, where these assumed circles intersect, draw a line to H, and also a line through C produced to F. These lines will be perpendicular to each other, because CDH is in a semicircle. Then find I by making HI, and CI parallel to the other two lines. Through I, draw BIF, and AEI. Then F and E are the centers of curvature respectively of the hypocycloid and epicycloid passing through D, described by rolling the circle CDH along the inside of the pitch

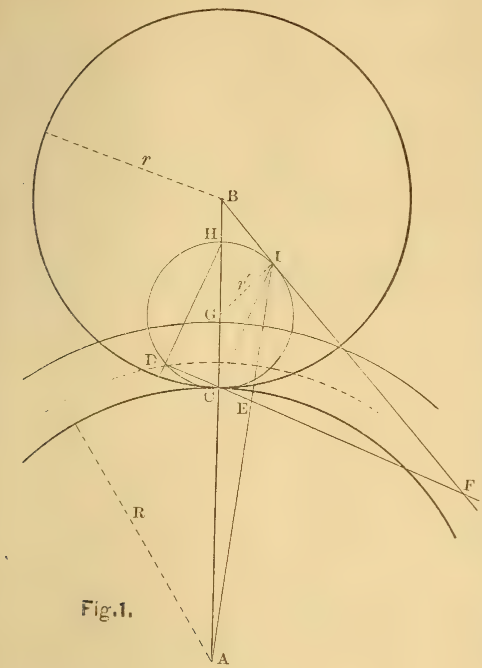


Fig. 1.

circle B, and outside the pitch circle A. Also DE is the radius of curvature of this epicycloid, and DF of the hypocycloid at D. This completes the diagram as far as required for drawing the approximate epicycloid through D for a face of A, and for drawing the approximate hypocycloid through D for the flank of B upon which the face of A, just obtained, works.

To show that DE and DF are the required radii of curvature: call R the radius of A, r the radius of B, and r' the radius of CDH. Then $CH=2r'$ and by geometry

$$CD=HI : CE :: R+2r' : R$$

or

$$\frac{CE}{CD}=\frac{R}{R+2r'}$$

But the radius of curvature of the epicycloid for A is

$$\rho=CE+CD=CD\left(\frac{R}{R+2r'}+1\right)=$$

$$2CD\frac{R+r'}{R+2r'} \quad (1)$$

the same eq. as given in Rankine's *Machinery and Millwork*, p. 60.

Similarly for the radius DF for the hypocycloid for B we obtain

$$\rho'=2CD\frac{r-r'}{r-2r'}, \quad (2)$$

the same as given by Rankine and others.

We have then a very simple diagram for arriving at these radii and centers of curvature.

The diagram may be abridged a little in practice. Thus, it is only necessary to draw ACB; the Pitch circles A and B; the assumed circle G; to find D at a third the height of the face; to make HI=CD; and find the intersections E and F.

In assuming the circle G, any diameter may be chosen. If it equals CB, the flanks will be radial, and the smaller it is the more will the flanks be curved. A few trials will enable the designer to hit about right.

As regards the height of the point D, taken at a third of the face, any height would lead to very good results, but the third is found to be about the most satisfactory.

Having, now, the radii and centers of curvature, circle arcs may be drawn if considered sufficiently accurate, but the Templet Odontograph will give much better curves.

To set the odontograph, it will be only necessary to measure the length of the radii DE and DF in inches and tenths, to obtain the setting number. For instance, if DF were $2\frac{1}{2}$ inches, then $2\frac{1}{2}$ is the proper number to look out on the scale of the odontograph as indicated by the dash at the graduated edge of the instrument shown in Fig. 2. In other words, the number $2\frac{1}{2}$, as indicated in Fig. 2, is to be brought to the point D, Fig. 1, while the hollow edge of the instrument is to be brought just tangent to the line DF. This can be very conveniently done by remembering that the $2\frac{1}{2}$, for instance, is exactly the distance in inches

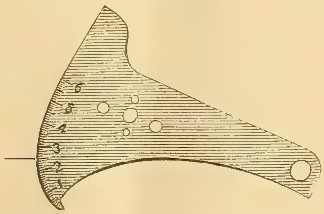


Fig. 2.

from the dash, Fig. 2, to the point of tangency in the hollow edge, as above stated. Then DF, Fig. 1, being 2½ inches, if a sharp pencil or other point be placed at F, and while the hollow edge of instrument slides against it, we bring the 2½ point of scale at D, we have all correct, and ready for tracing the tooth curve through D, by passing the pencil or scriber along the convex curve of the instrument.

In a similar manner proceed to trace the curve through D for the radius DE. The latter should start from the pitch line of A and will form the face curve for a tooth of A, while the former should start from the pitch line B, and will form a flank curve for B. These positions of the odontograph are shown in Fig. 3.

After once having found the true position of the odontograph for one face of

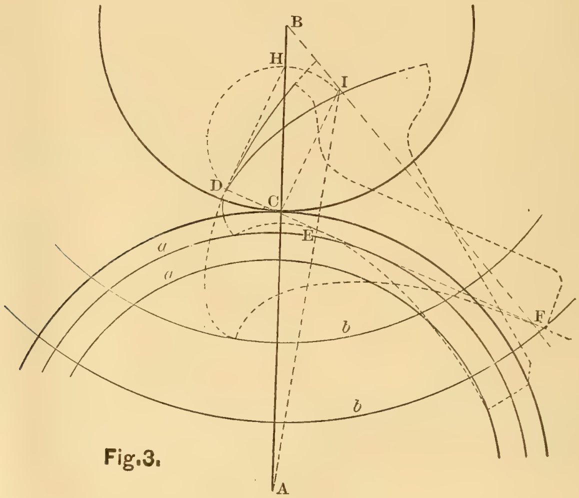


Fig. 3.

A, it may be transferred to the other teeth in two ways. One way is to attach it to a radius rod so that it will swing around. But the other way will probably be preferred by most draughtsmen, and consists of simply passing the pencil around the point and heel of the instrument while in position, and then drawing circles, *aa*, concentric with the pitch line A through these points, as shown in Fig 3. Then by placing the instrument with point and heel against these circles, and in the right place for any face, that face is readily traced. The same procedure holds for concentric circles *bb*, about B, for flanks.

If it should ever be desired to trace convex flanks, it is only necessary to assume the circle G with a diameter greater than BC. In this case F falls to the other side of C.

So far, we only have the faces for the teeth of A, and flanks for B. To obtain the faces for B and flanks for A, we only have to repeat the construction with A and B interchanged. In practice, this can be done on the same diagram as that which Fig. 1 represents, but for clearness it has been omitted here. But the two diagrams are entirely independent of each other; the lines DEF differing except when the wheels are equal.

2d. *For Internal Gearing.*—For this the figure becomes somewhat modified for the reason that we now have epicycloids running upon epicycloids, and hypocycloids upon hypocycloids; instead of epicycloids upon hypocycloids as before.

Fig. 4 will indicate how to proceed. Having the pitch circles A and B, assume the circles G and G′, and find the points I and I′. Lines produced through I and I′, from A and B, will give the center points EF, and E′F′, with which the tooth curves are to be found as before. G′ may be assumed infinite, or, in other words, simply draw a tangent CD″ to the pitch lines at C. Then E′ and F′ fall at C. The points corresponding to

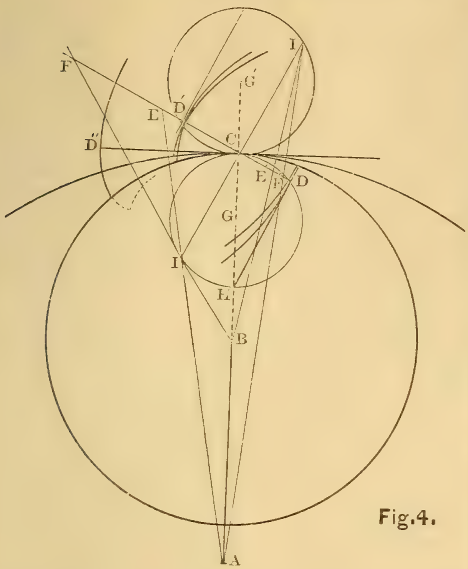


Fig. 4.

D, Fig. 1, are to be found as in that figure at a third the height of face. In this figure D′F′ is made to coincide with DF for clearness of figure.

3d. *For Rack and Pinion.*—Proceed as in Fig. 4, except regard CA as infinite. Then EI is parallel to CB, and the diagram is as in Fig. 5. For this case a

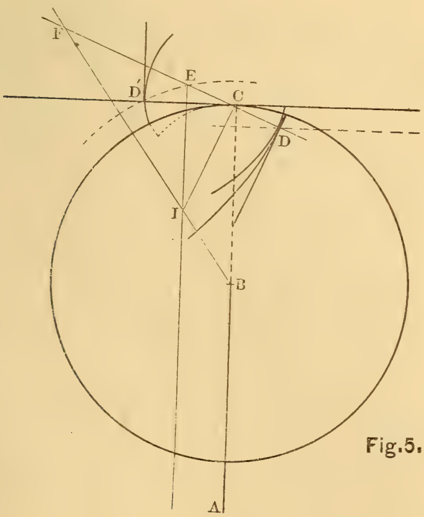


Fig. 5.

good result is obtained by always assuming the circle corresponding to G′ infinite, or, simply taking CD′ on the pitch line CD′ of the rack. CD′ will then be the radius for the face of the pinion, while the flank will have an infinite radius and be straight and perpendicular to the rack pitch line.

II. FOR APPROXIMATING TO TEETH WITH STRAIGHT FLANKS.

1st. *Flanks Radial.*—This case is very simple. In Fig. 1 we have only to make CH=CB, and hence Fig. 6. The points

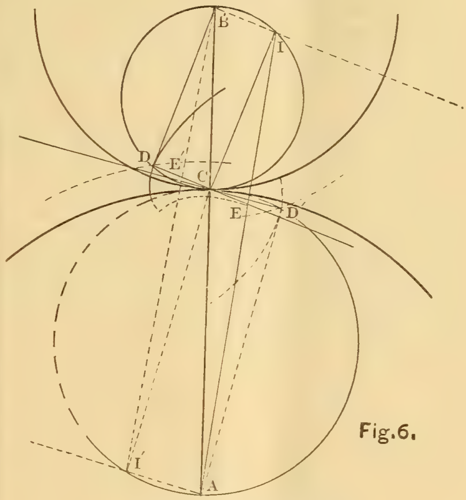


Fig. 6.

F are at infinity. This would make the flanks straight; and the fact that DB and D′A are radii of the pitch line, makes the flank radial. The odontograph is here only to be used for the faces of the teeth, and its setting is made upon the radius of curvature DE, or D′E′, as already explained, by measuring the radius and using the length in inches as the setting number.

2d. *Flanks Straight and Parallel.*—This is a peculiar form of tooth, said to have been first put to practice at the Lowell machine shop. Examples of drawings of it were exhibited at the Centennial by the Mass. Institute of Technology. It is, however, simply a special case of a general solution described in this Magazine in August, 1876, p. 99, Fig. 2; and, according to Willis, due to De La Hire. It is a special case in that the flanks are straight. But the construction is simplified in avoiding the laying off of certan angles by constructing the faces by drawing numerous circles and taking their envelope. This latter so reduces the work as to give to this form of tooth its turning point of success. For a description

of this method for straight circular and other flanks, see a recent number of the *Polytechnic Review.*

From the well known fact that one tooth can be assumed, and the other, upon which it is to work, found; we readily see that any assumed straight flank will have its correct face of a tooth of the other wheel upon which to work. For our present purpose, therefore, we only seek the radius of curvature of this face by the aid of which, together with the templet odontograph, that face may be traced.

By referring to Fig. 6 or 7, we find E the correct center of curvature of the face drawn through D, because the diagram, as regards E, is the same as in Fig. 1, and the same eq. (1) applies. Also the epicycloid DJK, Fig. 7, is the one that would be generated by rolling upon the pitch circle A, the rolling circle CDB, with its tracing point D.

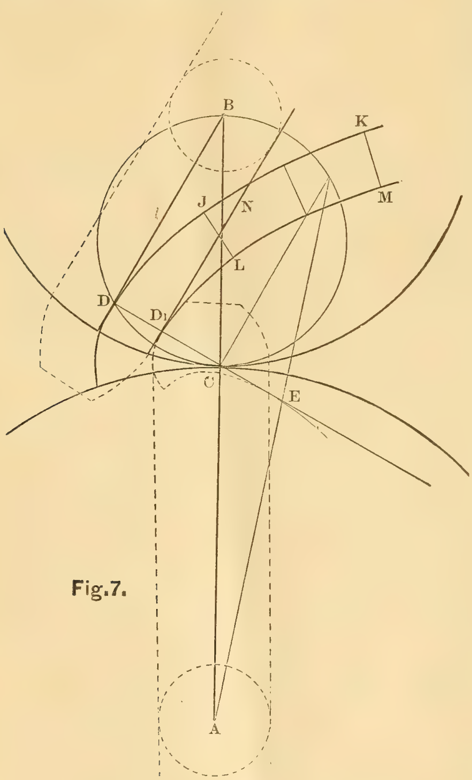


Fig.7.

Now if we draw a curve D_1LM parallel to DJK; that is, made equally distant by laying off on normals DD_1, JL, KM, etc., equal lengths, we see at once that the point E is the center of curvature of the new curve at D_1. Also it is easily seen that if DJK works correctly upon DB, as a face upon a flank; so D_1LM, parallel to DJK, will work correctly upon D_1N, parallel to DB. Again it is evident that DD_1 may be assumed at pleasure, and, of course, can be made equal half the tooth thickness. This assumption makes the two flanks of any tooth of B, absolutely straight and parallel.

Hence to draw teeth with straight and parallel flanks, proceed as in Fig. 6, except instead of D, take the point D_1 a half tooth thickness from D, and at one-third the height of a tooth face from the pitch line of A. This can probably be best done by first drawing a circle to the center B with a radius equal DD_1 or half the thickness of a tooth, and then form a right angle at D_1 with a triangle, one side against the circle, and the other at C. Thus all the flanks are tangent to the circle at B, and hence easily drawn.

The length ED_1 in inches becomes the setting number for the templet odontograph, by which a curve, closely approximating to D_1 LM, can be drawn with that instrument in the usual way.

Of course, by interchanging A and B and repeating the above construction, we get the other faces and flanks.

3d. *Flanks Straight, but Inclining at any Angle Toward, or From, Each Other.*—That this form may be realized is at once apparent from the last above, from the fact that DD_1 may be assumed of any other value than the half tooth thickness, and the circle at B drawn. Prolonged tangents to this circle will form the flanks. Also what is true of B, is true of A.

Internal gears, rack and pinions, etc., can easily be made with teeth of these forms.

III. FOR INVOLUTE GEARING.

The new method of setting can easily be applied to this form of tooth. The diagram is given in Fig. 8. A and B are the pitch lines. Draw the circle AEC and find a point E at a third of the height of a face of B. Draw the straight line ECE′, and the perpendiculars EA and E′B. Then E and E′ are centers of curvatures for involutes at C; and these can then be drawn by aid of the templet

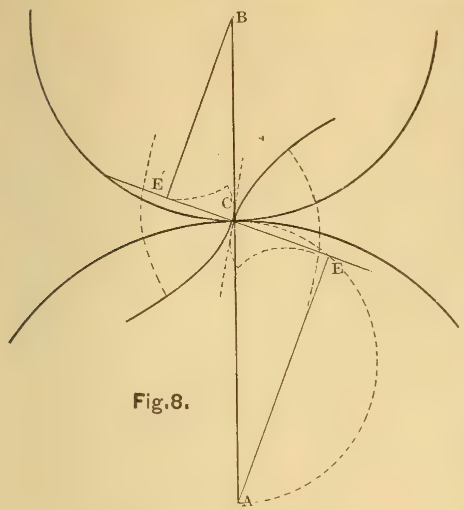


Fig. 8.

odontograph with the lengths EC and E′C, as setting numbers.

Only one line ECE′ is here admissible, because the whole side of a tooth of each wheel depends upon the one line.

We might add a method of setting the odontograph which was pointed out by Professor Reuleaux, Director of the Royal Polytechnic Academy at Berlin; and printed in a German publication. It combines the graphical method with the use of the odontograph tables. It is shown in Fig. 9. A and B are the pitch

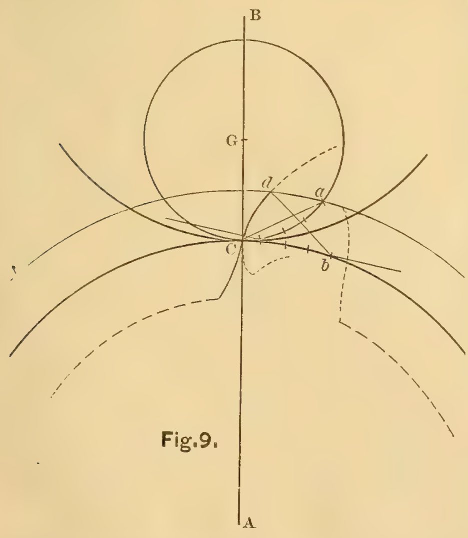


Fig. 9.

circles, and G the rolling circle to describe the faces of A, and flanks of B. Draw the addendum circle for A through *d*. This cuts G, at *a*. Now with spacing dividers, step off to C on the circle G, and back equal spaces to *b* on the pitch circle A. Then take the chord *a*C, and lay off an equal length *bd*, giving the point *d*, on the addendum circle. This point will be a point in the epicycloid sought.

Now with the proper setting number found by aid of the tables, the odontograph may be brought to the tangent to the pitch line at the middle of tooth as usual in the method of setting by the tables, and with the edge of the instrument at the point *d*, trace the face curve.

The point *d* is seen to be correctly located in the true face curve from the fact that as G rolls along A, *a* will fall at *b* and *a*C will coincide with *bd*.

In this way of setting the instrument, the setting number must be obtained from the table with due regard to the particular circle G assumed. To this end the radius of B, divided by the diameter of G, becomes the "degree of flank curve" for the other wheel, mentioned in the tables and rules.

In the German publication above mentioned, one point appears to have been overlooked in that the circle on which the chord C*a* is to be taken was given as the pitch circle B, instead of rolling circle G. This may, however, have been due to an omission by the printer, or engraver.

The various methods of laying out teeth above given have been devised, as a remedy for the feeling of uncertainty in the result obtained by setting the odontograph by aid of the tables alone, as directed in the article of July, 1876. In the present methods the diagrams carry certainty with them, in the check they afford; and, it would seem, could leave but little if anything to be desired.

The teeth can, of course, be finished off by introduction of root curves, etc., in the usual way.

M. H. Tresca has been elected president of the Société des Ingénieurs Civils of Paris. M. Tresca was president in 1862, and is now elected for the third time.

TRAMWAYS.*

From "The English Mechanic."

Tramways are now a recognised mode of working urban and suburban traffic; they have made their way into public favor in the face of persistent opposition, and, instead of being removed, will probably ultimately become the only public means of conveyance on the main roads leading to and between our principal towns. Tramways are not railways, it is true, but Mr. Clark is justified in protesting against tramway-engineering being regarded as but a humble branch of the profession. On the contrary, tramways require the exercise of the highest skill that can be found, for just as railways in their infancy were often failures, so tramways have arrived at the present degree of efficiency after a series of blunders. They cost more for working expenses than railways, and they earn more per mile, but they are, of course, cheaper to construct. Such a work as Mr. Clark has placed before us was much wanted. Sooner or later steam or some other mechanical power will be employed to haul the "ponderous cars," for Mr. Clark is not alone in the opinion that the employment of horse-power in the work of starting and dragging, often on severe gradients, heavily loaded tram-cars is an element of barbarism much out of place in a civilized country. It may be true that steam-cars, or the locomotives at present devised for drawing the cars, are not all that could be desired; but it is nevertheless a fact that where they have been tried under suitable conditions they have answered the purpose very well, considering that, as yet, they stand very much in the same position that Stephenson's Rocket did to the magnificent machines that came after it. The withdrawal of the steam "dummies" (a dummy is a steam-car, the engine and boiler being carried on the same platform as the passengers) from the Market-street route in Philadelphia gave rise to the idea that steam was a failure: the fact being that the company had not enough dummies to work the traffic, and so, having to keep as many men to look after three as would suffice for twenty, and having, moreover, to run those three in conjunction with cars drawn by horses the advantages of steam were discounted. The dummies are, however, objected to, because, in summer especially, they are hot and smell badly, and it is consequently seen that the direction in which to look for a more successful application of steam to street traffic is in the shape of a locomotive, like that of Hughes or Merryweather. But in that direction we are met by two difficulties. To employ a separate motor is to lose the adhesion of the car itself; and if the engine is made heavy enough to provide sufficient adhesion to enable it to drag the car up any gradient on the road, it is probably too heavy for the permanent way, which will consequently require continual and costly repairs. The self-contained or steam-car has, therefore, one great advantage over that drawn by a locomotive—that it is best adapted for the tramways at present laid; but there is no doubt that when once Parliamentary sanction is obtained for the employment of steam or other mechanical power, without unnecessary restrictions, the demand for motors will be met by the invention of the engine required. Mr. Clark divides his work into five parts, and presents us with an enormous collection of facts carefully arranged for the guidance and instruction of the engineer and the capitalist. His first part is a history of the origin and progress of tramways, from the early timber rails employed 200 years ago to the elaborate arrangement of rails, ties, and sleepers adopted in this country and abroad. The wooden tram-rails were occasionally plated with wrought iron, but in 1767 the Coalbrook Dale Company determined to protect their oak rails with cast-iron, because the price of iron being very low, and not wishing to blow out the furnaces, they were in a difficulty as to stocking. Accordingly they cast the iron into pigs 5 feet long, 4 inches wide, and $1\frac{1}{4}$ inches thick, with three holes, through which they were fastened to the

* Tramways, their Construction and Working. By. D. K. Clark, C.E. London: Crosby Lockwood & Co.

timber rails. By this means they made the iron help to pay the interest by reducing the cost of repairs, and the pigs were there at any time when wanted. The modern tramway was first employed in the United States, where, owing to the badness of the roads and the long distances to be traversed, a rapid means of transport was the first necessity to the pursuit of business. The New York and Harlem line was opened in 1832, but did not meet with favor, and was for a time suppressed. In 1852, however, M. Loûbat, a French engineer, laid down a tramway in New York, consisting of rolled iron rails placed upon wooden sleepers. The rails had a wide groove in the upper surface, and were similar to those afterward laid down by the same engineer in Paris. Tramways had by this time become so essential to New York that the objections made to them by the proprietors of other vehicles were disregarded, and they multiplied rapidly, not only in the Empire city, which owes most of its amazingly rapid development to them, but in the principal towns of the States.

Mr. Clark speaks of the "fearless manner" in which the rails were proportioned, but they were tolerated because the tramways were of more importance than the comparatively few vehicles which traversed the streets. In 1856 a Mr. C. L. Light, an English engineer, laid an improved tramway in Boston, in which the depth of the groove was only ⅜ inch, while the inner side of the rail formed a flat slope. The Philadelphia step rail was also an improvement, dispensing with a groove altogether, but having a ridge at one side against which the wheel-flanges ran; it answered its purpose well, and is still in use in that city, while a similar pattern has been adopted for New York. In fact, the step-rail may be said to be that most generally used in the United States. When introduced to England by Mr. Train it was speedily condemned, and the lines laid by him at Birkenhead and the Potteries were only saved from suppression by the substitution of flat grooved rails of the kind with which we have since become familiar. The modern practices, for there are several methods still, as it were, under trial, are fully explained in Mr. Clark's book, and the numerous woodcuts and lithographic plates render his work of great value. The present practice of tramway construction forms the second part of the book, and the many tables of cost and working expenditure which he has inserted in part three will be studied with attention by the municipal authorities and capitalists Part four introduces us to what may be termed the mechanical portion of the subject, although it is confined to a description of tramway cars. It is impossible, within the limits we can devote to a notice of this book, to give even an outline of the many details of the numerous cars which Mr. Clark describes. It must suffice to say that examples of the best constructions are fully illustrated, and that the latest improvements are noticed, down even to Eade's reversible car, which was patented in 1877. This car is swiveled centrally on the underframe, so that after the locking apparatus is unfastened, the driver can turn the car round without leaving his seat. This arrangement avoids the necessity for shifting the horses and pole, and the car is, of course, constructed with only one door and two staircases to the roof, one on each side of the platform. Mr. Clark says it is reported that the reversible car effects a saving of 30 per cent. in the horse-power required—a stud of eight horses working it as efficiently as twelve work the ordinary car. Eade's car is unusually light, weighing empty only 34 cwt, while one wheel on each axle runs loose. The alleged saving in power is, of course, due to the lightness of the car not to its reversibility. It is in use on the Salford tramways. The fifth part, Mechanical Power on Tramways, will be of most interest to the great majority of readers, for the development of the tramways system depends almost entirely on the application of mechanical power for their working. The report of the Select Committee issued recently will probably give a stimulus to the introduction of steam and compressed air motors, though they will still be hampered by restrictions which seem, to those familiar with engines, to border on the absurd. Mr. Clark in his historical sketch of the application of mechanical power to tramway cars, commences with Latta's "dummy," put on the Cincinnati Tramway in 1859. The

earlier efforts of Trevithick and others are ignored as not, strictly speaking, belonging to the subject. Mr. L. J. Todd was, however, the first engineer to bring forward any practical designs for the employment on roads of steam-propelled tramcars; and, we believe his engines were the earliest which met all the conditions imposed—viz., the absence of noise, smoke, and steam, with the possession of the power of stopping and starting quickly. About the same time Dr. Lamm experimented with an ammoniacal-gas car, and demonstrated the practicability of the invention; but the necessity for preventing all escape of the gas, together with its chemical action on iron, led Dr. Lamm to abandon for a time his ammonia engine in favor of the fireless locomotive, which consists of a strong well-clothed reservoir filled with water at a very high temperature. The fireless locomotive is running on the line about six miles in length, between New Orleans and Carrollton, the stationary steam-generator being at the latter place. The reservoir of the locomotive is filled with cold or preferably warm water, and then is connected to the Carrollton boiler, and steam of 200 pounds pressure forced in. The water is thus quickly heated and a pressure of about 180 pounds per square inch obtained. The contents of the reservoir is about 60 cubic feet, and in practice it is found to contain sufficient steam to run the car from Carrollton to New Orleans and back without reducing the pressure much below 50 pounds. The exhaust was discharged into the atmosphere making clouds of moist white vapor. Two other fireless locomotives were tried on the East New York and Canarsie Tramway, but they were not so successful as Dr. Lamm's. About this time Mr. Baxter, in America, and Mr. John Grantham, in this country, brought out steam-cars. Baxter's had an engine with compound cylinders and carried 54 passengers; and Grantham's, which was the first steam-car actually built and tried in England, had a boiler on each side of the body, in the center of its length with the engine underneath. It carried 44 passengers and worked well enough on the trial line at Brompton, but failed when tested on the line between Vauxhall Bridge and Victoria Station. It was removed to Wantage, but was unfitted for the inclines and curves of that tramway. It was subsequently altered by the advice of Mr. E. Woods, who replaced the two separated boilers by one, which was completely boxed in, and served to divide the car into portions, leaving a passage at one side communicating between the first and second class divisions. One pair of the wheels was used for driving and one wheel of the other pair ran loose, for ease in passing curves. It accommodated 60 passengers, and its estimated cost, from experience of its work on the Wantage line, was less than 4d. a mile run. Mr. Woods recommended that the Grantham car, built for the Vienna tramways, should have the boiler and engine placed at one end, while instead of the loose wheel on the undriven axle, he proposed a four wheel bogie. This car was fairly successful, but the boiler though a rapid generator, was too limited in water room, and required very skillful management. On a good road the working speed is from 10 to 12 miles per hour. In 1874 Mr. Loftus Perkins designed a tramway locomotive for a Belgian company. It was worked at a pressure of 500 pounds on the square inch, and had compound engines, the high-pressure cylinder being single-acting. The steam exhausted into an air surface condenser, consisting of a number of copper tubes. The boiler was of bent iron tubes $2\frac{1}{4}$ inches in diameter (inside) and $\frac{3}{8}$ inch thick, tested to 2,500 pounds on the square inch. Coke was the fuel, the draught being due to the height of the chimney alone. The speed of the crank shaft was reduced by toothed gearing in the ratio of four to one, and the motion was taken off the second shaft to the wheels of coupling-rods. At the commencement of its working life this locomotive was reported to be perfect—"no smoke, no escape of steam into the atmosphere, no noise, no feeding of water during the trip, nor even, if needful, for several days." The high pressure, however, rendered it very difficult to maintain the joints, and after altering the engine, the Belgian authorities concluded to take it to pieces and sell it as old metal. Mr. Perkins has, however, recently improved his design, and Mr. Clark says at the

conclusion of an elaborate description, accompanied by an excellent lithograph, that "it is anticipated that very economical results of performance will be obtained by the use of this locomotive. The Société Métallurgique et Charbonnière of Belgium constructed a tramway locomotive in 1875, with a Brotherhood three-cylinder engine and a Bellville "inexplodable boiler," the speed being reduced by spur gear. It resembles an omnibus in appearance, and altogether is scarcely likely to become the motor of the future. Of the numerous devices that have been tried we can only allude to Francq's improved hot-water locomotive, in which the steam from the reservoir is admitted to an intermediate chamber, where it is maintained at a fixed pressure; to Todd's hot water steam-car, in which the reservoir and machinery is carried beneath the floor; to MM. Bède & Co's hot-water steam-car which has been running regularly and successfully in Belgium, and to the engines of Merryweather, Hughes, H. P. Holt, Ransom, and Baldwin, the two former of which are well known from description, already published. Most of the designs are illustrated by diagrams, and some have large lithographic plates devoted to them. It will be understood, from what we have said, that Mr. Clark's work is a perfect treasury of tramway facts, but it is even more than that, because some of his chapters are occupied with dissertations on the principles of tramway construction and working, in which points apt to be overlooked by inventors are carefully considered. Cars, he thinks, should be constructed on double bogies, or, still better, on radiating axles, and they should have a longer wheel base than is now usual. The results obtained with the Paris omnibus car, Mr. Eade's car, and Mr. Cleminson's flexible wheel-base car, point to the desirability of starting afresh with new ideas, and recasting the design of the tramcar. The production of a noiseless, vaporless, smokeless, and handy machine will not come from those who too slavishly follow the old lines; but of the present devices Mr. Clark awards the palm, as first in order, and foremost in practical performance, to the Merryweather, which in Paris and in other parts of the Continent has been doing effective service on the tramways, "causeless of annoyance or hinderance to the ordinary traffic of the streets." It is too much to hope that this work will lead to the prompt withdrawal of all vexatious restrictions on the use of mechanical power for propelling street cars; but, while it places a vast amount of practical information before the engineer, it serves to enlighten those who may ultimately have to decide whether a mechanical power tramway shall or shall not be allowed in the districts over which they have control.

COTTON POWDER OR TONITE.

From "The Engineer."

One of the marvelous applications of chemistry is the discovery of the modern explosives known as nitro-glycerine, gun-cotton, dynamite, litho-fracteur, and under other names. The late war, and especially the destruction of the two Turkish monitors, the general introduction of torpedoes and torpedo vessels, the destructive explosion at Stowmarket, the disaster, fearful in every sense, at Bremerhaven, have directed even popular attention to these extraordinary substances. Like other forces of nature, powerful servants but evil masters, these materials render very great services in many operations; and, in case we have a war, our control of the manufacture of most of them should be of the greatest importance. There is now a competitive struggle going on between the different blasting explosives in the market, and only time will tell which one will obtain the mastery. All of them evolved in the laboratories of chemical analysts, their introduction has undergone many vicissitudes; and enormous labor and sums of money have had to be spent before they could be rendered practically

useful. On the introduction of gun-cotton by Schoenbein in 1846, great expectations were at once raised, experiments on a lavish scale were carried out with it, especially by the Austrian Government; but in the course of a few years it was relegated to the laboratory shelf. About 1860, Sobrero introduced his nitro-glycerine; but Herr Nobel had to render it practical by mixing it with an earthy absorbent, producing what is now called dynamite, before it could be rendered what may be termed chemically stable and a fairly safe article for blasting purposes. Again taking up gun-cotton, Professor Abel has rendered it similar services, mainly by pulping its fibre, and by thus rendering the texture uniform, enabling it to be more thoroughly washed. The Stowmarket explosion, however, showed the necessity of using it in the wet state, as it was fortutunately discovered that it could then be exploded by the use of a strong primer of dry gun cotton.

As we are all accustomed mentally to compare an explosive with ordinary gunpowder, at first sight scarcely anything is stranger than to see a quantity of matter embodying an appalling amount of explosive force harmlessly burning away like a candle. But the comparative safety attending the use of modern explosives known under the names of gun-cotton, lithofracture, tonite or cotton powder, is due to the fact that they cannot, under ordinary circumstances, be exploded without the application of a special detonator. But most of them are liable to more hidden and insiduous influences. While gunpowder only explodes by the heat generated by friction, or by the direct application of a flame or spark, dynamite, for instance, is liable to explode unexpectedly while being thawed; and the union of the nitric radicle with the glyceric elements being of a weaker character than the similar union in gun-cotton, it follows that the original nitro-glycerine of dynamite will not resist the external disruptive forces that can be applied to gun-cotton—such as accidental concussions. This has been proved theoretically by M. Berthelot, well known for his work in these departments of applied science. He found by direct experiments that the mean of the molecule of the radicles gives less heat in the formation of nitroglycerene than is the case with gun-cotton and that the ratio of these values also gives the value of the ability of the compounds to withstand disruption. The habitual practice of the respective manufacturers in supplying detonators twice as strong for gun-cotton as for exploding dynamite is unwitting practical proof of Berthelot's discovery. Dynamite is thus probably out of the question for general use in military operations, on account of its property of freezing at a comparatively low temperature; and it is an open question whether the damp compressed gun-cotton now supplied to the British army and navy, could be exploded in a mine laid overnight in frosty weather. It has often been stated that dynamite could be thrown on a fire without causing an explosion; and this might indeed happen, but we should be sorry to be present at several such trials. Compressed gun-cotton, while wet of course, stands this fire test very well; but it can only be called wet when there is no occasion for the necessity of its standing this test at all, or when it is stored in water-tanks. Once out of such tanks the water begins to evaporate, and, in fact, some of the gun-cotton must be dried before any can be used. Hence, as in the case of thawing dynamite, dry gun-cotton has to be put in close proximity to heat, and as the substance is then highly inflammable and porous, there is liability to an explosion.

In theory there is only one element to be taken into account in estimating the blasting value of an explosive, namely, the total heat it can evolve. But in practice, on account of the very different amounts and natures of the resistance of the bodies to be acted upon, a time element is introduced. The element of space is also a not unimportant factor. For instance, if 1 pound of compressed gun-cotton and 1 pound of common gun powder be confined within a solid resisting mass of rock or metal, it will be found that the pound of compressed gun-cotton contains less than twice the energy of gunpowder. If, on the other hand, equal quantities by weight of the two be exploded freely on a common iron rail, while the gunpowder would cause a mere puff of smoke, the gun-cotton would completely shatter the rail. The

rate of explosion of compressed gun-cotton is nearly 18,000 feet per second. This extreme rapidity of explosion enables the inertia of its own mass to act as sufficient tamping, while the comparative slowness of the gunpowder explosion gives the gases full liberty to expand in the measure as they are generated.

It is a necessity inherent to the very nature of any explosive that it cannot ever be termed absolutely safe; it is only comparatively safe under certain known conditions. Thus, a great recommendation of ordinary gunpowder, when made with sulphur free from sulphurous acid, is its chemical stability; it also explodes at a high temperature, but its hardness makes it liable to ignite by friction; and, differing from the new blasting explosives, it is easily exploded by a spark. But it is the chemical stability, mainly due to the knowledge acquired during the centuries of time in which it has been manufactured, that makes it so much safer to store. The great danger from ordinary gun-cotton is this, that it is liable to chemical changes subsequent to manufacture. Such changes seem to be due to irregularities in the composition, to mechanical and chemical non-homogeneousness. This tendency to alteration is corrected by the system of grinding, boiling, and washing, which removes any free acids and organic compounds mixed with the fibre. But in spite of all this, it has still to be kept and used in the wet state, which if leading to nothing worse, is conducive to miss-fires. It is also liable to another danger. Its combustion or explosion evolves carbonic oxide, one of the most poisonous gases known, and the cause of the late accident in the Holywell district, by which one miner was suffocated and fifteen more or less injured.

There is a form of gun-cotton known as tonite, or cotton-powder, which is said to possess rather peculiar properties. It is tolerably well known as a marketable commodity, and manufactured on a large scale near Faversham. Tonite consists of finely divided or macerated gun-cotton compounded with about the same weight of nitrate of baryta. The gun-cotton itself is mainly common cotton waste steeped in nitric acid, and on the excess being forced out by a hydraulic press, or otherwise, it is left some time for digestion in vessels of clay. Necessarily while in the moist state, the fibres are macerated or disintegrated between crushing rollers. In order to give this substance what is to be complete chemical stability, it is subject to washing processes, the *rationale* of which is a secret of the maker, and which complete the manufacture of the gun-cotton. Tonite consists of this macerated gun-cotton, intimately mixed up between edge-runners, with about the same weight of nitrate of baryta. This compound is then compressed into candle-shaped cartridges, formed with a recess at one end for the reception of a fulminate of mercury detonator. In the fact of its being easily fastened to the safety fuse, it contrasts very favorably with soft, plastic, dynamite. Amongst the advantages said to result from the use of the nitrate are that it contains a great amount of oxygen in a very small volume; and that it is very ready under the detonator, while its great density makes it slow to the influence of ordinary combustion. By the employment of nitrate of baryta it is claimed that this explosive cannot merely be made much cheaper than ordinary gun-cotton, but that the same weight is about 30 per cent. stronger. It may seem incredible, but a tonite cartridge is no more liable to catch fire than a piece of soap, which it resembles; its great density causes it to burn very slowly if set fire to, and so slowly that all danger from a too violent generation of gases is obviated. While, therefore, the railways of the kingdom absolutely refuse to carry dynamite and compressed gun-cotton, they regularly take tonite on the same footing as gunpowder. The tonite cartridges are generally waterproofed. The density is such that it takes up the same space as dynamite, and two-thirds of gun-cotton. There can be no doubt that much original chemical thought has been practically applied by the officials of the Cotton Powder Company, and they claim, probably with justice, to have taken a lead in the introduction of processes for the purification of nitro-compounds—in other words, to have given them sufficient chemical stability as to obviate those dangerous internal changes subsequent to manufacture at the bottom of so many disasters.

ARTIFICIAL MARBLE.

From "The Building News."

A PROCESS of making artificial marble has been recently patented in England on behalf of Harriet G. Hosmer, of Rome, which differs from previous processes in the fact that limestone in the solid state is employed as the base instead of a mixture of plaster and cement. The limestone is worked by any suitable means to the desired form, and is then placed in a boiler furnished with a safety-valve and manometer, so that the pressure therein may be noted and controlled as may be required. The boiler is then filled with pure water at the ordinary temperature, care being taken that there is no mineral deposit introduced with the water. Care must also be taken that the water completely covers the objects placed within the boiler. The boiler is then hermetically sealed, and fire applied, and the water allowed to boil until the manometer indicates five "degrees" of atmospheric pressure if the objects are small, and six or seven degrees of pressure if the objects are large. When the heat reaches the above-mentioned point the water is allowed to cool until the pressure indicated by the manometer returns to zero. The water is then taken out of the boiler, either by means of a pump or a siphon, and the objects are removed from the boiler preparatory to being placed in the alum or colored bath. If, however, steam alone can be introduced into the boiler (always maintaining the above-mentioned degree of heat and pressure) the result attained will be the same, the action of the steam, not the presence of water, being necessary for acting on the stone. When it is desired that the objects should retain the natural color of the stone, the alum bath should consist of pure water containing five degrees of alum, as indicated by the areometer. The articles must remain in this bath at least twenty-four hours, but they may be left in the same bath for a week, or for a month even, by which time they will acquire still greater hardness. The stone will, however, have become sufficiently petrified for all ordinary purposes in twenty-four hours. If pure water be used in the boiler, according to the process first described, instead of steam, the alum bath may be effected in the boiler itself, thus avoiding the necessity of removing the objects; but it must be remembered that the application of alum is only admissible when it is intended to preserve the natural colour of the stone. In such case the alum is put in the water before the boiling commences, and the objects must remain in the boiler for 24 hours after the pressure, as indicated by the manometer returns to zero. The articles, when taken from the alum bath, may pass into the hands of the polisher if in the form of plain blocks, slabs, or flat pieces, but if they be in the form of statues, busts, vases, columns, or other ornamental works of art, they may be placed in the hands of an artist to finish, if required, as the stone does not attain its greatest hardness until it has become perfectly dry, which will require a fortnight, more or less, according to the size of the object. When it is desired to impart color to the stone the colored baths are prepared in the manner indicated below, in which the objects must be immersed, and must remain therein at least 24 hours. The colored baths must be boiling, or very nearly so, and it is better to remove the objects to be colored from the first boiler and place them in the colored liquid while they are still warm from the steam or water. There is no danger, however, of injuring the stone, even if it should be put into boiling liquid while cold, or into cold water while the articles are still heated, but the color penetrates deeper when both stone and bath are in a heated state. If it be desired to place an object a second time in the colored bath in order that it may acquire a deeper colour it should first be placed in an oven at a temperature of from 80 to 90 degrees, in which it may remain ten minutes, after which it may be immersed in the colored bath. To produce black or dark grey color take of pure water 2 litres; red wood, 300 grammes; fustic wood, 120 grammes; sulphate of iron, 10 grammes; sulphate of copper, 2½ grammes. Boil the red wood and fustic wood

for an hour and a half, then add the sulphates, and continue the boiling until all the salts are dissolved. Three or four minutes will probably be sufficient for this purpose, the solution may then be passed through a sieve, and half a tumbler of acetic tincture of iron added. Stone color or lighter grey is obtained in the same manner, with a weaker solution. In order to prepare a red coloring solution take of pure water 3 litres; Brazil wood, 330 grammes; Scotaus (*sic*), 5 grammes; cream of tartar, 1 gramme; alum, 1 gramme. Boil the mixture until all the color of the wood is extracted, and then pass the solution through the sieve in order to remove therefrom any solid matters that may be held in suspension therein. A yellow color is obtained by adding to three litres of pure water extract of yellow wood of Cuba, 20 grammes; sulphite of magnesia of alum, 10 grammes. The mixture must be boiled until complete solution of extract is effected. In order to obtain a green color dissolve in three litres of pure water extract of yellow wood of Cuba, 20 grammes; and 10 grammes of alum. Boil the ingredients as above and then add carefully (by means of a wooden spoon, and keeping at a certain distance) as many drops of acid sulphate of indigo (Saxon blue) as may be necessary to give the tone of color desired. To ascertain the depth of color pour a few drops upon white paper, or dip a piece of dry plaster of Paris in the solution. For a blue color dissolve alum, 10 grammes; acid sulphite of indigo, 20 grammes in 8 litres of water, until the desired color is obtained. As all the varied colors of aniline penetrate the stone perfectly, they may be used at pleasure. It is only necessary to dissolve the color selected in a little alcohol, which is afterwards diluted with warm water, in which alum is dissolved in the proportion of 24 grains of alum to every litre of water. The solution may be even stronger in alum; this is for colors which are insoluble in water. For such aniline colors as are soluble in water no alcohol is necessary. They may be dissolved in boiling water in which a little alum or sulphate of magnesia is introduced. Care must be taken to select only those colors which are durable. The same colors which are permanent in cloth are permanent in stone, and in general the same rules which apply to the art of dyeing cloth may be applied to the art of dyeing stone. Pavements which are colored, particularly if the color is very delicate, and if there be fear of dampness, are better laid down in cement of a light color. For the darker colors the cheaper dark cement is equally good. For the stone of which the natural color is preserved no cement is absolutely necessary unless the place in which they are to be laid is particularly damp. After the objects have been taken out of their respective baths they are allowed to dry, during which process the work may be re-touched, if necessary. When dry they are reduced to a fine surface by means of pumice stone, after which a still finer surface may be given by means of a piece of slate, or still better, of lead, after which they may be rubbed with oil. When the oil is dry the articles may be rubbed with phosphate of lime, and the lustre will be rendered perfect. The ordinary methods of polishing marble will apply to the polishing of petrified marbles prepared by the above process.

THE survey of the silver mines situated on the Comstock Lode was carried on in 1877 by Professor J. A. Church, of Lieutenant Wheeler's party. The character of the vein was carefully mapped from one thousand feet to two thousand feet deep. The heat varied from 84° Fah. in old drifts, to 116° in freshly opened workshops. The source of this heat is, it is believed with those in charge of the works, ascertained to be the decomposition of rocks under the agency of atmospheric influences. This was observed of the thick sheets of lava lying upon the vein in the upper 1,000 feet of rock. Below this, it is known to be going on for 1,500 feet further; at 2,400 feet it is nearly uniform, neither increase nor decrease is observed. The miners cut through singular bands of hot and cold rocks, a fact which seems to suggest that the origin of the local heat is the motion which is taking place is tangential and orthogonal directions in the earth's crust, as the result of its slow contraction by cooling. It is thought the lode will continue hot, but not increasingly so.

THE FLOW OF SOLIDS.*

By M. HENRI TRESCA, President of the Société des Ingénieurs Civils, Paris.

From "Engineering."

For all bodies two distinct periods are recognised—the period of perfect elasticity, which corresponds to variations of length proportional to the pressures applied ; and the period of imperfect elasticity, during which the changes of dimensions, on the contrary, increase more rapidly than the pressures. If the second phase of deformation be alone considered, it is easily understood that it leads finally towards a condition in which a given force, sufficiently great, would continue to produce deformation, so to say, without limit—such as may be observed in the process of drawing lead-wire. This particular condition, in which the deformation is indefinitely augmented under the operation of this great force, constitutes in fact the geometrical definition of a third period, which has been designated by the author as the period of fluidity, and to which the greater part of his experiments on the flow of solids are related.

The period of fluidity is more extended for plastic substances; it is necessarily more restricted and may altogether disappear in the case of vitreous or brittle substances. But it is perfectly developed in the case of the clays and in that of the more malleable metals.

In his paper of 1867, the author considered the deformations of these substances by flow under certain given conditions ; such as the flow of a cylindrical block through a concentric orifice, or through a lateral orifice, one of the most novel subjects of his researches ; also plate-rolling, forging and punching. It was there demonstrated that in these different mechanical actions the pressure was gradually transmitted from place to place, with loss from one zone to another, in absolutely the same manner as in the flow of liquids, and with a regularity not less remarkable, but following a much more rapid law of diminution.

The pressure may be very considerable at certain points, whilst it may be nothing at all at other points, and the study of the various modes in which pressures may be transmitted constitutes in fact a new branch of investigation to which M. de Saint-Venant has given the name of plasticodynamics. It is chiefly in the operations of punching metals that this mode of transmission of pressure has been manifested, whilst the processes of forging, on their part, have afforded the means of establishing the correlation between those molecular phenomena, and the development of heat which is their direct consequence.

With respect to the formation of the jets of solid matter similar to jets of liquids, one more experiment only will be referred to, of recent date, by which the likeness is completed, and becomes absolutely illusive.

Two half discs of lead, forming portions of a cylinder, four inches in diameter, were placed in juxtaposition in the compression-press, so as to form a whole disc. Under the pressure of the piston they resolved themselves into a cylindrical jet, identical in appearance with those jets which had previously been obtained, but formed in reality of two semi-cylindrical jets in perfect contact. Their surfaces of contact bore especial traces of the successive movement of the different layers, and reproduced the exact representation, in the solid state, of a sheet of water in motion.

Punching.—Regarded as a question of kinematics, the punching of various substances, as wax, clay, plastic metals, supplies instances of absolutely identical deformations. Shortly after the paper of 1867, some nuts which had been manufactured by punching hot, in England, and which were sent to the author by the kindness of Mr. Bramwell, enabled him to remark the same effects, still better developed by the phenomena of the drawing of the fibres, so well manifested in the specimens now lying on the table.

The two punches, which act in opposite directions, enter the block of metal from opposite sides, and the piece which is left between them is diminished in

* Paper read before the Institution of Mechanical Engineers.

thickness by flowing from the center towards the circumference, until, when the two punches are moved in the same direction, the piece reduced to a minimum thickness is shorn off and discharged outside.

The phenomena which take place in this metal, softened by heat, are such as would take place in a liquid ; and they lead us to expect that the deformations observed in punching lead should be produced similarly in analogous operations on the hardest of metals.

The author had already shown the inflexion and the curving of the fibres by the punching of discs of cold iron, at the works of MM. Cail & Co., and also the same phenomena in the burrs which were punched out; but he had not been able, on account of the insufficiency of his apparatus, to obtain, with iron, as much reduction of the height of the burr, as was obtained in his experiments with more plastic substances.

The section of one of these burrs, taken in a vertical plane through the axis, does not admit of any doubt of the deformations produced.

In a special memoir presented to the Academy of Sciences, on the 31st December, 1869, the author endeavoured, on the basis of an enlargement of the burr in the zone of fluidity, as it is called, just under the punch, to establish a general formula for the measure of the reduction of the height of the burr, taken into account the whole height of the burr, its diameter, and the diameter of the punch. The height L was given by the formula:

$$L=R\left(1+\log.\frac{R}{R_1}\right)$$

in which R and R_1 represent respectively the radius of the burr, supposed to be cylindrical, and the radius of the punch.

When the punch penetrates it forces the material to spread laterally, until the moment when the solid unaltered portion below presents a less amount of resistance to shearing than is applied to the continuation of the lateral spread. This argument suffices to show that all burrs of the same section should be of the same height.

By the results of another and supplementary series of experiments, it was established that for all the different materials, subjected to the same action, the results were substantially alike, and corresponded exactly to the dimensions given by the formula.

But, at that time, the author was unable to experiment with blocks of iron sufficiently thick to embrace a range of evidence as to the reduction of the height of the burr, such as had been obtained with other materials; and it is only quite recently that the results of experiments on punching made in America have appeared, and have in a remarkable manner confirmed *à posteriori* the results of his previous investigations.

Several specimens of these punchings, very skilfully prepared by Messrs. Hoopes & Townsend, have been forwarded from the Philadelphia Exhibition, to the author. But the burrs proved a little longer than the lengths as deduced by means of the formula; the fact being that the blocks which were sent had been planed after the burrs had been punched out, to dress the faces. When the actual unplaned blocks arrived, they satisfactorily confirmed the algebraic formula.

The reduction of height seemed at first incomprehensible; and it can only be explained by the flow of a portion of the material into that of the block. It is to be remarked, too, that the lower face of the burr is convex, and the upper face is concave; with respect to the latter, the punch only crushes the material at the edge, whilst the middle of the face, notwithstanding the forced passage through the block, retains the original tool-marks.

The formula is deduced, as has been seen, from certain hypotheses on the mode in which pressures are transmitted; and though it be only a particular case of more general formulas, cited in the author's memoir on punching, it retained somewhat of an empirical character. Thanks to the researches of M. Boussinescq, in his theoretical essay on the equilibrium of pulverulent masses compared with that of solid masses, it takes its place as a rational formula, and it may therefore be accepted with complete confidence.

In one specimen only of all those which have been prepared by Messrs. Hoopes & Townsend, the pressure exerted by the flow of the metal has burst the block, and, on a close examination of the

bottom of the cavity formed by the punch, in consequence of the mode by which the pressure was transmitted, all the features of the results of the explosion of a projectile there may be found.

A few more sketches of punched blocks are added, showing precisely the contortions produced in the lines of junction by the passage of the punch.

It would be unpardonable if, on this occasion, no mention were to be made of the remarkable experiments on iron compressed when cold, the results of which have already been presented at the Vienna Exhibition, and which have until now been only received with doubt, and even with incredulity.

Can the quality of iron be really improved by cold-compression? There is no longer room for doubt as to this, in view of the recent researches of Professor Thurston, and the numerous specimens which are to be found in the collection of Messrs.Hoopes & Townsend, with the actual particulars of the forces under the action of which they were ruptured.

Speaking now only of the experiments with nuts when punched cold, Professor Thurston's tables indicate a considerable augmentation of resistance relatively to nuts of the same dimensions made of the same iron, and punched hot. The trials were made, either by applying to the rod which carried the nut pressure sufficient to strip the thread, or by introducing into the unscrewed nut a conical mandrel sufficiently loaded to split the nut. The augmentation of resistance due to cold punching may be taken at an average of 25 per cent. and this result can only be explained by supposing that there is some modification of the molecular condition of the surrounding iron, which has been subjected to compression by the flow from the mass of metal driven out by the punch.

Forging.—If it be necessary to justify the expression, flow of solids, in the case of forgings, it is only needful to prove it by the inspection of a collection of specimens of rail scalings, found on the Eastern Railway, near Epernay. Each blow is in some sort represented by the formation of a wave, and drawing-out has taken place in this fashion, by the formation of successive scales for a length of several decimetres. Deformations produced by forging only differ from this mode of displacement of the molecules in this, that they are produced for a certain purpose, and at a temperature at which the metal becomes comparatively soft.

The object of the author's early discussions on the forging of iron was to show the tendency to parallelism of all the fibres which originate in drawing out under the hammer, and which are separated from the neighboring fibres by a cementing substance derived from the incorporated cinder, which fills up all the void spaces between the fibres. This matter is frequently of a vitreous nature, very rich in oxide of iron, and when it is not burned off or pulverized at the surface of the piece when in the hands of the smith, it follows all the varieties of form to which the piece is shaped in its several parts. It has been shown, nevertheless, that the deformation may be only superficial when the action of the hammer was mild, whilst the influence of a more powerful blow, such as is practiced in industrial operations, may be felt to the core.

An oblong piece of iron may then be compared to a hank of parallel threads, which will interlock with each other when it is attempted to draw them out lengthwise, but which will separate in a much less regular manner when they are drawn in the crosswise direction, at the risk of throwing into confusion the regularity of the original arrangement; forming knots and voids which must evidently weaken the power of resistance which would be possessed by the piece under other conditions.

This effect is well exemplified by the specimen of a railing bar, in the formation of which a rectangular bar is transformed, in respect of its transverse section, into a number of rectangles and circles regularly distributed, the fibres in the circular parts losing the parallelism which is visible in the rectangular parts. This condition would certainly be critical, were it not that the central part of the enlargements was afterwards to be bored out.

The interposition of the friable silicates between the fibres, which are more properly metallic, ought to be seriously taken into consideration in this case as in many

others. At present a few of the more characteristic facts may be noticed.

From the fact that iron wire of good quality is capable of supporting, before giving way, loads much greater than ordinary iron, a manufacturer of best scrap iron tried to work it from piles exclusively composed of wire. A longitudinal section of the bars manufactured in this manner, having been oxidized, reveals the filiform structure of the bar much more clearly than any of the specimens of merchant bar iron. There is exhibited a specimen taken from an old railing at the Conservatoire which broke spontaneously in its place. Having a greater proportion of the silicates in its composition, which had been imperfectly removed in the process of forging, this specimen exactly reproduces an analogous type.

On the contrary, when the best Swedish iron is submitted to the same operation it gives but the faintest indications of longitudinal striæ, which sometimes can only be produced by taking special pains with that object.

The irons which are the most effectually purged of silicates are the best, but the expulsion of oxides formed during reheating on the surface of bars designed to be faggoted is of great importance.

The variously colored appearances that may be raised on well-polished sections, either by a deposit of copper, or by the action of an acid, or, better still, by the action of bichloride of mercury, show clearly the arrangement of the fibres, enabling us to trace, through all the deformation of a piece, the molecular displacements which, but for that demonstration, would remain undetermined.

The treatment by a very weak solution of hydrochloric acid, first employed in the Low Countries by M. de Ruth, is so effective, that by inking the surface, indented at the parts of least resistance by the action of the acid, proofs may be taken, in which the direction of the fibres is perfectly distinguishable. By the employment of chloride of mercury, the indentations and the fibres are much more neatly and delicately defined.

Without reverting to the examples given in the first paper by the author, he will now give other instances in illustration of the most ordinary results from the fibrous constitution of the metal.

On the basis of the evidence supplied by the oxidation of polished sections of iron, M. Le Chatelier sought to separate the siliceous matter which envelopes the fibres of the metal, by exposing the iron, at a red heat, to a current of chlorine. The iron is volatilized by this process, and leaves a skeleton as the residue, having the form of the original piece, composed of extremely fine filaments, and resembling, more than anything else, the residue left by a match which quietly burns without inflaming, supposing that the ash is prevented from being pulverized.

This siliceous carcase scarcely amounts in weight to a hundredth part of that of the metal, but it was associated with a certain proportion of iron, which completely disappeared in the course of the operation.

It has been stated that these silicates are friable when cold; and it appears that, with the object of diminishing the wear of bearings, the journals of shafts are sometimes hammered, in order to pulverize this interposed foreign matter, and entirely to clear it away from the rubbing surface.

Iron, by its constitution, lends itself much better to drawing out than to setting up. The difference is well exemplified in the case of a wagon axle which has been bent while cold. If it be divided down the center in a plane, the fine ribbon-like appearance is clearly brought out, and the lines are very exactly concentric. In the convex portion, it might be believed that the lines were described with compasses. In the concave portion, on the contrary, the fibres are broken and confused; at the same time, there are two fractures by compression, whilst the exterior face remains entire. Here the texture would have been altered to a still greater extent if the iron had been heated for the operation, when the metal would have been brought to a consistency like that of putty.

The deformations transversely are much better shown in a square axle four inches square, the surface of which had been subjected to a series of blows from a center-punch, at intervals of 0.4 inches. The convex portion has been extended so much that the width has been re-

duced from four inches to 3.20 inches, and the concave has, on the contrary, been spread out to a width of five and a half inches, in proportion as it was shortened in length. The simultaneousness of such deformations is well known, and they are the more pronounced as the curvature is decreased. But it is specially important to note, in this example, that the fissures which are produced are situated only in the compressed portion, whilst the portion principally submitted to extension has continued perfectly sound.

For the purpose of testing the soundness of the welds in rails the rails are frequently subjected to a series of torsional stresses in two opposite directions, which usually result in a number of longitudinal fissures of greater or less length, in the lines of separation of the component bars. But, in operating on a shaft turned out of a square bar of good iron, much more conclusive results are obtained. By the application of excessive torsional stress, the fibres are forced into relief, and the iron shaft absolutely assumes the form of a rope, in which all the exterior fibres are apparent. But the constitution of the interior of the shaft is still more remarkable. If a transverse section be taken it is easy to discover, by the agency of oxidation, the sinuous lines which correspond to the exterior helices, and of which the equation is precisely given by calculation, assuming that the angle of torsion is constant for all points of the shaft.

Supposing such a piece were to be raised to a welding heat and forged anew, it can scarcely be doubted that an iron of exceptionally great resisting power would be produced, possessing, in some degree, the best properties of metallic cables.

The ribbon-like constitution is never better manifested than in iron plates, in which it might often serve to reveal the mode of manufacture. In iron tubes, for example, which are manufactured mostly in England and in France, the regularity of the lines is such that it is only interrupted at the weld; and a means is afforded for ascertaining whether the weld has been made by simple contact, or by lapping.

The same manufacture demonstrates also the inconvenience which may attend compression. In the section of a nut for an iron tube, it is made evident by the mode of striation that the hexagonal form is produced by drawing out from a circular section, outside as well as inside. The layers are, at some points, separated towards the angles, where it was necessary that the section should be enlarged by squeezing or compression.

The object to be kept in view in the various methods of forging should be, according to the foregoing discussion, to dispose the fibres in the direction which best accords with the use to which the piece is to be applied. Mr. Haswell, director of the workshops of the Southern Railway at Vienna, has attained this object by stamping in dies piles which are suitably prepared. The author has had oxidized several of the pieces manufactured by this process for railway service; and it is clearly manifest that, though, here and there, the silicates occupy too much space, and are not regularly diffused, the fibres are, nevertheless, arranged in the most favorable direction in all parts of the section.

At several other iron works, the example of Mr. Haswell has been followed, in the manufacture of pieces by stamping, particularly at the iron works of Niederbronn. But no doubt iron of the best quality should be employed, in order to derive from this method of manufacture all the advantages which it promises.

The defects of the system are well exhibited in the section of a key forged by the stamping process from a bar of iron doubled twice over on itself.

In all operations to which iron is to be submitted it is important that the particular form of its constitution should be regarded. The excellent iron plates of Berry, which may be easily doubled, because their different layers are not sufficiently susceptible of being welded, could not, for instance, be subjected to the American mode of punching, with a punch which, being faced with a helicoid surface instead of the usual flat surface, manifestly tends to tear, at the edges of the hole, the different parts of the same layer.

Heat Developed in Forging.—The study, geometrically, of the deformations produced by forging considered under the simplest conditions, has led, from another point of view, to results which,

though they are not translated into definite figures, are, nevertheless, of some interest, whether having regard to the deformations themselves, or to the calorific phenomena by which they are accompanied.

When a square bar of iron is compressed between two horizontal flat jaws, equal and opposite to each other, the bar is flattened and elongated, and the experiments already made on the crushing of metal discs afford grounds for believing that each vertical fibre of molecules is deflected into a sinuous form, analogous to the forms produced by the crushing of a cylindrical block consisting of a pile of plates. When a prism is partially flattened the flow of the material placed under the tool is resolved into an elongation having a curved surface, of which the directrix is a logarithmic curve. The equation of the curve might be given, but it is useless to enter here into theoretical speculations. It will suffice, meantime, to mention the result, and to apply it where necessary in the course of the discussion.

In a special example of deformation obtained on a bar of lead by the blow of a hammer, the distortion very much resembles those which have been already illustrated.

If each of the four faces of the prism be divided into squares of one centimeter, or 0.40 inches wide, the comparison of the figures will show all the changes which take place on one of the sides. A small enlargement of 0.12 inches is produced on the upper face and the lower face, but this may be neglected at first. Towards the middle of the depressed portion the intermediate horizontal lines present their convexity in contrary directions towards the center-line; and the two verticals near the center vertical, have, on the contrary, their maximum separation from each other at the level of the center.

The two opposite squares, having a width of 0.12 inches show respectively two symmetrical depressions; but it is the four squares formed by the diagonals which manifest the most complicated distortions. In proportion to the depression produced, the subjacent matter is expelled both transversely and logitudinally; but the second displacement is that which it is most important to take into consideration with respect to the elongation to be produced, and it is the only displacement which can take place, when the piece is forged by stamping.

The elongation in the interior of the compressed portion being gradual, the depressed edge resulting from it necessarily presents an inclined face. It would theoretically take a logarithmic form, of which the curve would unite nearly at right angles with the original face above, which is displaced longitudinally, and, at the bottom of the depression, with the depressed portion of the same original face. This exterior side of each of the original faces of the square is thus drawn into a form analogous to that of a letter Z, of which the inclined member has been bent over in the opposite direction. The three other sides, elongated or shortened, constitute the locality of the greatest deformations; and it is to this to which the whole attention should be directed. The original lines, as well as the resulting deformations of these lines, are illustrated with absolute exactness by a figure.

It is thus shown what takes place under the action of the first blow of the hammer. The second blow should cross the first blow, when it is required to reduce the height for the whole length of the bar ; and an idea may be formed of the new deformations and the re-straightenings which take place, by examining the figures, in which the dividing lines are reproduced after each of three or four successive blows, one after the other. In spite of the care which was taken, the deformations are not sufficiently symmetrical, but they are characteristic enough to remove any doubt as to the distribution of the molecular action to which every part of the mass has been submitted.

The forged bar presents extended portions, and compressed portions, and the result of the work would evidently be the best possible if the vertical lines, successively deformed in two different directions, resumed a rectilinear arrangement after each deviation. The forging would then consist of a methodical series of the effects of deformation, immediately followed by the effects of a corresponding rectification.

Such effects become still more complex when the bar to be forged is not sustain-

ed between lateral guides by which all lateral extension is prevented. It is evident that new deformations will be presented under such conditions, which will modify those which have just been analyzed, and attention should be directed more particularly to the semicircular protuberances which are distributed over the length of the piece, in correspondence with each blow of the hammer.

These nipples form a kind of network produced by the forging, describing on the lateral surface a series of lozenges with curved sides, separated by the half circles already mentioned.

These undulations of the surface, which are of no importance in the geometrical operation of forging, nevertheless deserve notice, as they indicate the zones of maximum sliding, which are also the zones of the maximum development of heat ; and the author has been enabled, by their indications, to connect the phenomena of forging with those of thermodynamics. It has long been known that heat is developed by the forging of a metal, and in some operations connected with the *platinage* of steel, pieces of steel subjected to blows rapidly delivered, may be raised to a dark-red heat. This phenomenon does not ordinarily take place, except in working thin sheets ; and it will be shown that, in working thicker pieces, the precise situation of the greatest development of heat can be recognized.

In a forging operation which the author has had to conduct on a large scale on an alloy of iridium with platinum, a phenomenon occurred incidentally which engrossed his whole attention, bearing intimately as it did on the deformation of solid bodies. He may be permitted to refer to it, though the experiments are not yet completed ; and it will be a source of great satisfaction to him to make known the first results of these experiments to an assembly of English engineers before any publication of them elsewhere.

On the 8th of June, 1874, the author simply announced the main fact at the Academy of Sciences, that when the bar of platinum, after having been forged, had cooled to a temperature below that of red heat, it happened several times that the blows of the steam-hammer which at the same time made a local depression in the bar and lengthened it, also reheated the bar in the direction of two lines inclined to each other, forming on the sides of the piece the two diagonals of the depressed part ; and this reheating was such that the metal was in these lines fully restored to a red heat, so that the form of these luminous zones could be clearly distinguished. These lines of augmented heat remained luminous for some seconds, and presented the appearance of the two limbs of the letter X. Under certain conditions as many as six of these produced successively could be counted simultaneously, following one another according as the piece was lifted under the hammer so as to be gradually drawn down for a certain part of its length.

The appearance of these luminous traces can be explained beyond all doubt. They were the lines of greatest sliding, and also the zones of the greatest development of heat—a perfectly definite manifestation of the principles of thermodynamics. That the fact had not been observed before was evidently owing to this, that the conditions necessary to be combined at the same moment had not been present under such favorable circumstances. Iridised platinum requires for its deformation a large quantity of work to be expended upon it. The surface takes no scale, and is almost translucid when the metal is brought up to a red heat. The metal is but an indifferent conductor of heat, and its specific heat is low. All these are conditions which are favorable for rendering the phenomena visible in the forging of this metal, whilst it has remained unobserved with all others.

Although this explanation was what was to be expected, the author nevertheless proceeded to justify it by experiments of a more direct character, of which some account will now be given ; and which constitute the chief motive, and it may be added the chief point of interest in this communication.

Given a bar of metal at the ordinary temperature, if, after having coated it with wax or with tallow on two faces, it be subjected to a single blow of the steam-hammer, the wax melts where depression is produced, and it is observed that the melted wax assumes in certain cases the form of the letter X, as

was observed in the case of the platinum bar. In other cases the limbs of the cross are curved, presenting their convex sides to each other. The heat has then been more widely disseminated, and the wax melted over the whole of the interval by which the curves are separated.

The prism which has this melted outline for base, and for height the width of the bar, represents a certain volume, and a certain weight; and if it be admitted that the whole piece has been raised to the temperature of the melted wax, the elevation of temperature represents a certain quantity of heat, or, in the ratio of the mechanical equivalent, a certain quantity of internal work which is directly exhibited by the experiment.

In comparing this work with the work done by the fall of the hammer, a coefficient of efficiency is obtained which amounts to not less than 70 per cent. This value cannot be taken as final; it depends upon the conductibility of the metal, on the stiffness of the apparatus, on the clearness of outline of the melted surface. But what the author is desirous to impress upon the meeting is that here there is a return to the first methods of Mr. Joule, and that the author's investigations of the flow of solids conduct him to certain thermodynamic demonstrations.

The following are the numerical data for some of the experiments, together with the illustrative figures:

(*See Tables on following column.*)

Name of Metal.	Work of the Ram.	Form of the Impression.	Area of Wax melt'd	Thickness of the Forging.
	kgm.		sq. ct.	cent.
Iron....	80	Rectangular	1.45	2.5
"	90	"	1.50	2.5
"	110	Wide-spreading	2.20	2.5
Copper.	60	Rectangular	1.75	2.0

Volume of the Corre-spondi'g Prism.	Correspond-ing No. of Heat-Units (Heating to 50 deg. C.).	Equivalent Work, at the Rate of 435 kgm. per Caloric.	Proportion Percentage of Total Work converted into Heat.
cu. cent.		kgm.	
3.63	0.1498	63.72	0.796
3.75	0.1547	69.79	0.731
5.50	0.2269	96.44	0.877
3.50	0.1329	56.48	0.942

In the last experiment, taking as melted the area of wax included between the hammer and the crosses, a useful effect of 94 per cent. is obtained.

Stamping.—The object of stamping is to dispose the relative displacement in given directions, in order to pass from the primitive form, supplied direct by the maker, to the definitive form which is desired to be accomplished. From this point of view, the die is a kind of channel designed to facilitate the flow of the material, and to guide in the most suitable direction or directions. When it is required to draw down by stamping a square bar of iron, each blow of the hammer causes transverse enlargement as well as elongation; and the useless enlargement is advantageously obviated if it be prevented by the presence of the sides of the canal. If it be well to employ the stamp in simply drawing down a bar, how much more indispensable is it when the variation of form is more complex? The simple idea of flow supplies material for forming a rational judgment on the successive dispositions of the stamps required for the intermediate operations; and also on the adjustment of the sections of rolls, which are but circular stamps or moulds, by means of which iron is drawn out.

That all these phenomena are but various forms of flow, of which in most cases the circumstances can be anticipated, may be shown by other experiments which will now be described.

The most characteristic of these experiments is, perhaps, the following:

Having completely effaced the reverse in relief of a piece of money, place the flat surface on a sheet of lead, and flatten the second face in the stamping press. The whole relief of this face will be produced on the face which had been reduced to flatness; and the design of this relief will even be imprinted on the lead. This effect is explained by the circumstance that each vertical thread or fibre of molecules, being separately compressed in the direction of its length, flows, when struck, with greater facility into the lead than into the other parts of the piece. The saliencies, as reproduced, are less, no doubt than in the or-

iginal relief, whilst the more delicate features are partially obliterated, but the general effect is reproduced and it is apparent that the flow takes place in the direction of the depth, which is also the direction of least resistance.

On the reverse of the sheet of lead, which has necessarily been reduced in thickness by the effect of the imprint, the image will be found repeated in a more confused manner, and it may be distinguished by a peculiar tint which indicates a well-defined geometrical transformation; the lead having flowed in a horizontal direction, as the only way of escape when its surface was depressed. This amplification or enlargement takes place in the proportion of 22 to 13, when the plate of lead was ½ inch thick.

An entirely different effect is produced when a medal is struck. The blank piece having been placed in the matrix, the portions which are not to be raised in relief by the action of the press are reduced in thickness, for the benefit of the neighboring portions which are raised; the metal literally flowing, in radial directions, from the hollows to the reliefs by which they are surrounded.

If the medal has only an engraved face, it may be made up of several blanks of equal thickness superposed. The same mode of distribution of the molecules takes place, and is manifested by successive imprinting at each face, in which the final relief is more or less obliterated.

It is so clearly a manifestation of flow that takes place under these conditions, that if the bottom of the matrix be hollowed out at the center, then, the material which converges from the circumference exciting a pressure towards the center, the central portion of the blank is driven towards the orifice, where it forms a very regularly shaped boss; admitting of the transformation of a relief, executed on a plane, into a similar relief on a surface which has become very convex or very concave, according as the design pertains to the upper or the lower face of the blank.

To an analogous cause, the presence of scars sometimes observed on medals highly relieved, is to be attributed; these scars being produced simply by the junction, during the later strokes, of the edges of the bosses which are formed by the earlier strokes.

When the medal is relieved on both faces, if it be made up of several plates superposed, it is interesting to remark the successive developments and effacements of the images on both sides of the plates; mingling and merging in each other in a singular manner.

Rules cannot yet be formulated for the best forms of the grooves of rolls; but it may be accepted that they should be shaped in such a manner as to utilize as far as possible the natural flow of the metal in the direction of the pressures applied to it.

It has been shown that, when a bar is to be drawn out, it is best to prevent any enlargement of it laterally, and to facilitate the longitudinal flow; the die should, therefore, be carefully gauged, short, and opened out in the direction of the length.

It has been seen, also, that in stamping a disc, it may be useful to make use of centripetal compression. Each mode of action has thus its own mode of deformation of which it is necessary to know how to take advantage. The following is a very remarkable instance: Given a disc of lead 4 inches in diameter and ½ inch thick; if it be pressed, in the stamping machine, for a diameter of 2½ inches at the center, the thinning of this central portion is only effected by the flow of the material outwards; and this flow is exactly symmetrical, when the centering is perfect. The exterior border is developed in the form of a tulip. By such means, without the employment of a matrix, geometrical forms of a perfectly definite character may be produced, which may be useful in some cases.

This general disposition of material had been long since observed by MM. Piabert and Morin, in the course of their experiments in drawing out blocks of clay. Around the orifice of entry the clay was thrown out in the form of acanthus leaves, and the same development is to be observed in the displacements which take place when projectiles are discharged against armor plates. The metal displaced by the projectile is driven forward in flakes or strata more or less involved and dislocated, which have, nevertheless, a striking family likeness to the dispositions previously noticed.

The geometrical condition of the de-

velopment in tulipform of the plate of lead may be very simply explained. The border of the plate, which makes an effort to retain unaltered its diameter and its thickness, continues to be attached to the central portion, the gradual crushing of which throws out rings which are successively thinner and thinner. These rings have, therefore, at each instant, a given thickness, and by their succession they necessarily form a surface of revolution, which is accurately calculable, on the hypothesis, which is perfectly justifiable, that the volume is constant.

The conditions of such development may be modified by the employment of casings of various forms; but attention will be confined to the case of a concentric casing so disposed as to prevent any increase of diameter.

Eight discs of lead 1½ inches in diameter having been placed in a cylinder, a piston of 1.20 inches in diameter is placed upon the pile formed by these plates. Since the material can only escape from the compressive action by the annular space comprised between the piston and the cylinder, it ultimately assumes the form of a sort of tumbler, of which the height is extended to the length of the piston, even beyond the length of the cylinder. The thickness of the tumbler, 0.15 inches, would have been more regular if but one disc of lead, or of tin, had been employed. But the mode of distribution of the layers in the thickness of the tumbler is in itself a useful subject for consideration. The uppermost plate has been developed, almost in one piece, to the upper edge of the tumbler, being connected by a continuous supplementary part, which becomes gradually thinner until it reaches the foot of the tumbler. The other plates are also developed, in a parallel direction, supported by the sides of the cylinder, for a length which may be submitted to the same kind of calculation as that of the plates of the concentric jets. It is the same mode of deformation applied, in the present case, to an annular jet; and the complete analogy between the formulas which give expression to their relations is not one of the least remarkable facts in these transformations.

This method has for several years been adopted in industrial operations, under conditions of precision which are truly astonishing, in which a vertical and cylindrical jet, 12 inches high, is manufactured from a sheet of tin perfectly smooth and of uniform thickness. In the finest specimens of that size, the ends of the tube, which are pared after having been struck, do not show any irregularity exceeding $\frac{1}{12}$ inch in height, even though the cylindrical envelop has been suppressed for the whole height. The substance driven out in the form of a ring, the thickness of which is measured by the difference between the radius of the punch and that of the matrix, is naturally disposed to form a thin cylinder, the several elements of which slide with equal facility upon the perfectly polished surface of the punch.

A thousand examples of similar surprises may be found in industrial processes ; but this instance, amongst them all, definitively sanctions the expression by which the author believes he is authorized to designate the results of his researches. The flow of solids is now recognized in science; much more will it be accepted by the members, who are witnesses every day of the processes which are based upon it, as the true expression of the best ascertained facts.

Planing.—Of the various operations which have been described above, that of punching is the only one which has had for its object the dividing of a solid body, and forming two entirely separate parts—the burr and the punched block. The block is augmented by compression of a portion of the matter which constituted the cylinder which would have been simply pushed out by the punch, supposing that the cylinder could have slipped out without giving rise to other phenomena. The burr is reduced by the same amount.

Cutting or shearing does not really take place until the moment when the burr, in consequence of lateral flow, has been reduced to its height. It has been proved that from this moment the resistance opposed to shearing is actually proportional to the area of the zone of shearing. The co-efficient of resistance applicable to this separation is no other than the co-efficient of resistance of fluidity; or what amounts to the same thing, the co-efficient of resistance to rupture; so that we are now put in possession of a cer-

tain formula, applicable equally to circular shearing by the action of the punch, and to rectilinear shearing by the shear blade or by the turning tool.

In each case one of the parts of the piece slides upon the other part, producing at the two sides in contact a drawing out of the successive layers, which are bent over in the direction of the length of the shorn surface, in thin shreds, like those produced by the punch. The separation only really takes place at the moment when these shreds are drawn to their extreme limit of tenuity.

This characteristic of the separated surfaces is met with in planing, although the principal circumstances may here be entirely different; not less remarkable, however.

The principal difference consists in this, that the chief compression takes place, not in the solid mass as before, but in the cutting which is detached by the tool, which, as it forms the exterior portion, opposes to the flow the least resistance. If the cutting be compared with the space which it occupied in the block before separation, it is easily observed that it is at the same time considerably shortened, and that, consequently, its thickness has been augmented in the inverse of the shortening.

The leading fact in planing is very well exemplified in the turning from the wheel-tyre of a locomotive comprising a cutting for the rivets. These are represented as of an elliptical section, $1\frac{1}{8}$ by $\frac{4}{10}$ inches, showing that the reduction in length affected by the action of planing was in the ratio of 10 to 28, or 0.36. This co-efficient of reduction is still much greater than it is in many other circumstances; for the thinnest cuttings, the co-efficient is occasionally as low as 0.10.

In another instance, a cutting planed off transversely from a double headed rail, the height has not been altered, but the width has been reduced nearly in the same proportion as in the first example.

Another characteristic of cuttings produced by planing is that the surface of the cutting which rises from contact with the cutting-tool is always smooth, and is developed geometrically. That surface, in fact, is moulded on the tool during the process of deformation, and slides upon it in such a manner as to roll itself up in the form of a cone or of a cylinder. At this moment, above all others, the plasticity of the metal is brought into play; and if the original form of the cutting should interpose too serious obstacles to this development, it tears or splits according to the direction of the generating surfaces of contact, still responding to the geometrical condition first referred to. It is well to avoid such rents as much as possible, for evidently they cannot be produced without the expenditure of additional power. Such loss of power must take place, especially where it is required to reduce a curved surface at one cut, of great breadth. An example of such fissures is shown on about a third of the width of another cutting from a tyre; but those of the opposite edge are attributable really to a greater reduction of the length of the thinner edge in the process of planing.

The other face of the cuttings is always rugged and wrinkled with fissures or with transverse ridges, of very variable aspect, according as the metal is more ductile and the cutting is thicker. For the greater thicknesses both iron and steel present on that surface a multitude of inclined ridges partly covering one another ; and of which the incline is still better defined where complete separation has been produced.

These scales have been drawn just as they appear under the microscope, on a cutting of Bessemer steel. Nothing can show better than their general inclination the sliding that may be produced in planing, in consequence of the compression which is produced in front of the tool before the cutting is completely detached from the block.

In the greater number of cases the turning when long enough winds up into a helicoidal form, as may be seen on the cutting, of which the rugged face has just been shown.

The inclination of the spirals depends upon that of the cutting edge of the tool, and their diameter upon the thickness of the cutting; the diameter diminishing with the percentage of reduction. It is thus that, in turning in the lathe a piece which is very slightly eccentric, the result is a number of parts of which the diameters are alternately greater

and less. The demonstration afforded by this single specimen is quite complete.

Without seeking to draw any conclusions from the study of these deformations with respect to the best form of tools for each of them, it follows clearly from the foregoing discussion that the work required for any cutting action whatever is expended in friction and in deformation by compression. The work of friction should augment with the number of cuts, and as the shortening is greater for the finer cuts the molecular work expended should be greater. It follows, therefore, that it it is most advantageous to make deep cuts, but, of course, this mode of action demands more powerful tools and better foundations. It is in this direction, it appears, that the most recent progress in the manufacture of tools has been effected.

The different modes of cutting, rectilinear or circular, are applicable chiefly to flat surfaces and to cylindrical surfaces.

Flat surfaces are cut in the planing machine or in the lathe, and under most circumstances the two kinds of cuttings are almost identical in appearance—that of a cylinder formed of spirals more or less close, sometimes even in juxtaposition; but for this combination, it is necessary that the two edges of the cutting should have been equally reduced, that is, that they should be of the same thickness. If it were otherwise the spirals would become conical; and such of these as appear to be most characteristic will now be described.

The cutting obtained in mortising, by means of a straight tool, is absolutely cylindrical.

When the tool cuts out, in this manner, a rectangular groove, the material is compressed without any lateral deviation. If the cutting is of great thickness, it is triangular, and the smooth surface is formed by the combination of the three faces at which the separation takes place, the direction in which crumpling takes place being the same as in all ordinary cuttings. The triangular form is the result of the compression being greater toward the middle line.

To aid in forming an opinion on this point two blocks were placed side by side, which were planed at the same time, in the line of junction of the pieces. Two distinct horns were formed, which parted symmetrically from one another; each half-cutting following the law of shortening by which it was bound to assume a form concave towards the side which was held by its attachment to the block.

Having made a similar experiment in lead, the parallel and equidistant lines that were drawn upon the block before it was cut could be traced on the cutting, and they afforded the means of measuring exactly the average percentage of reduction, and the mode of contortion of these transverse lines, which assumed successively the same inclinations as they lay one upon another at intervals, of which the percentage of reduction varied from 0.10 to 0.30.

The cuttings from a lathe, when they were produced from an annular groove, by means of a straight tool, assumed exactly the same forms. For example, a cutting from a groove in what is called the Swedish piston is a continuous ribbon rolled up as on a bobbin, with the greatest regularity, and of great length, without a rent.

When turnings take the form of a helix, the small lateral displacement of the piece is not large enough to give to the ribbon a different character to that from a planing machine, when, for instance, it is required to turn a shaft to a uniform diameter, and it is then easy, with good metal, to produce cuttings of great length. But, when it is required to turn the end of the shaft or of any cylinder whatever, the cutting follows a special course. If the tool be large in proportion to the diameter of the rings or circles on which it is acting, the difference of diameter between the two edges of the cutting makes itself felt in the cutting, which assumes the form of a helicoidal surface, with inclined generating lines, of which the directrices are two helices of the same pitch but of different diameters. This universal geometrical character, moreover, is manifested in special ways according to the width of the ribbon and the interior diameter of the ring. In this way three horns may be obtained, encased one in the other, if the cutting edge of the tool be radial. Successive spirals foul each other when the direction of the cutting edge is a little inclined. The inner helix

is replaced by a straight edge when the tool cuts right to the center of the face.

Notwithstanding these differences of detail, the same rules prevail: a greater or less reduction or shortening, according to the thickness of the cutting; a less reduction of length at the thicker edge of the cutting; a smooth surface of separation, which always forms a developable surface; a rugged reverse face ridged as if waves of metal had been successively projected there; in fact, all the circumstances of a transverse flow of material—setting apart the secondary circumstances, of transformation of the prism of metal from which the cutting is produced by augmentation of thickness and corresponding reduction of length.

The author endeavored to represent, by a diagram, the triangular cutting which would be formed by planing from the edge of a block of metal a square prism, by means of a tool having two cutting edges, and of which the flat front is itself placed symmetrically. The effect of the diagram, constructed on the assumption of a percentage of 0.30, is exactly reproduced by the model in relief. In agreement with the foregoing discussion and with the facts, it may be observed how the prism which is on the point of being separated from the block swells up by compression, commencing at a certain zone of fluidity, of limited length, in advance of the tool; and how, when this compression has arrived geometrically at the maximum which could be sustained by the material, the cutting is detached from the mass to be subjected to the action of the face of the tool, upon which it slides, and which forces it to assume its ultimate form.

Considerable as these modifications may appear, they are absolutely in accordance with the facts. They have been produced by the author, on lead as well as on the hard metals, under conditions which were exactly proportional to those which are represented by the model.

The finest specimens of this triangular transformation of cuttings that have come under the author's observation, are produced by a mortising tool. They are not less than $\frac{6}{10}$ inches thick, and the rolling up of the metal could only be effected with the accompaniment of deep fissures in the lateral edges. The upper edge, on the contrary, is much more minutely serrated, one of the lateral faces is plaited for its whole length, evidence of the compression of the material; whilst the other face, with its oblique fissures, shows still better the sliding by means of which the compression takes effect.

There is a still smaller cutting which presents exactly the same characteristics.

It is the author's opinion, that for the construction of the best machine tools, with the most suitable thickness of cuts, the minute examination of the cuttings is of the greatest importance; and that by the same means, the surest evidence may be derived with respect to the qualities and homogeneity of the metal.

Time does not permit of more than a passing reference to certain deformations which recall to mind, with a surprising degree of exactness, the constitution of certain rocks, with their dislocations. A few experiments of this kind were made by the author in conjunction with M. Daubrée, from which the latter gentleman quite recently derived an explanation of a number of geological phenomena. The results of these inquiries would no doubt possess some interest for the members, but the author was desirous chiefly to lay before them such results of his investigations as followed in natural sequence upon the substance of the communication already made in 1867.

The idea of the flow of solids is, of all the modes of regarding their deformation, perhaps the one which most truly interprets all the phenomena of molecular mechanics, and of the internal constitution of bodies, which underlie the various industrial operations.

Mr. Samuel Sharpe has promised to give £500 towards the building of the North Wing of University College, London, so soon as the Council are prepared to begin the work. It is expected that this liberal donation, together with others which have been received, will enable the building to be very shortly commenced. A sum of £50,000 in all will, however, be required to complete the extensions which are immediately contemplated.

THE ACTION OF RAILWAY BRAKES.

From "The Engineer."

On Monday morning Captain Douglas Galton and Mr. Westinghouse resumed their inquiry into the action of railway brakes, which had been interrupted for a short time to enable certain alterations to be made in the construction of the recording apparatus in the experimental van. It will be remembered that the inquiry began on May 27th, and we illustrated the experimental van and commented on the results obtained in our impressions for May 31st and June 7th and 28th. All the alterations since made in the van refer to matters of detail, their effect being that the diagrams given by the recording apparatus are clearer and more perfectly trustworthy than before. Two ends of two carrying springs have been attached to levers which act on a water-pressure diaphragm, and by means of a Richards indicator, record the action of these springs. The system of scaling the diagrams has also been modified, but with these exceptions, what we have already said in the way of description will apply to all that follows. It may be worth while for the sake of rendering matters clear, however, to explain that six indicators are used to record—(1) The angular or tangential strain on the brake blocks; (2) the motion of the carrying springs of the van; (3) the force applying the blocks to the wheels; (4) the pull on the draw-bar of the van; (5) the speed of the van, the motion of the indicator being derived from the leading wheels to which only the brake is applied; while (6) is a somewhat similar indicator driven by a belt from the unbraked wheels. There are, besides, two Stroudley speed indicators in the van, employed to check the accuracy of the Westinghouse instruments just named.

On Monday morning the van drawn by the "Grosvenor" left Brighton station and ran to Hastings and back, several experiments being made on the road. Unfortunately, however, a portion of the brake rigging gave way during the experiments, and brought them to a close. On Tuesday morning, with new and stronger rigging, the experiments were resumed, and continued on Wednesday. We may be excused for not going minutely into the investigation of the results obtained, when we state that on the first day alone more than 120 diagrams were obtained, which will have to be compared and arranged and measured before definite results can be made public. This is a work of some time. We may, however, with advantage, indicate the nature of such phenomena as appear most worthy of attention.

The first point claiming attention is the failure of the brake rigging. This consists of a Y-shaped frame, the two limbs of the Y being welded to a stout transverse rod, the ends of which are prolonged beyond the limbs of the Y far enough to pass through the brake shoes. The single leg of the Y is connected by a system of levers with the piston rod of the air cylinder, and when the brake is applied the whole Y frame is put in tension, with the exception of the transverse bar, which is in compression. The diagonal bars or limbs of the Y are of $\frac{7}{8}$ in. round iron; the transverse bar is of $1\frac{1}{8}$ in. round iron. This bar gave way by bending in the middle on Monday. It was replaced by a much stronger rigging on Tuesday. The strain put on each brake block is precisely 100 times the pressure per square inch in the air cylinder when the brake is applied. This cylinder is 8 in. diameter, and the piston is consequently 50 square inches in area. Now the highest air pressure used during the trials was 95 lbs. on the square inch in the brake cylinder. This drove each block against the wheel rim with a force of 9,500 lbs., and under the strain thus brought to bear on the tackle, the horizontal extension rod gave way, as we have said, by bending. But this, like all the similar tackle used by Mr. Stroudley, had been tested in the shops with a pressure of 120 lbs. on the square inch, or 12,000 lbs. on each shoe, and had withstood the strain perfectly. The lesson to be drawn is that unless all the conditions under which any member of a machine has to operate are taken into account, the results of tests of endurance cannot be regarded as trustworthy. In the shop

the brake rigging while under strain was not subjected to any violent jarring action ; on the road the vibration set up in the metal was active, and promoted a rearrangement of the molecules of the bar. Bearing this in consideration, it is by no means to be regretted that the rigging gave way. The experience obtained is worth a good deal, and admits of very extended application. It illustrates the prudence of Lloyd's rule that when chains are being tested by tension they should also be struck sharply with a hammer; and it throws some light on certain so-called mysterious failures of structures to do the duty expected of them, and performed by them when originally tried in the maker's yard. We may here add that tackle of the kind which gave way has hitherto been found quite strong enough in regular practice.

The results obtained when the brake was applied under varying conditions, were exceedingly curious. We have already explained that when a wheel skids two things take place—(1) The angular strain on the brake shoes is enormously augmented for a moment; and (2) it then sinks to much less than it is when the wheel is revolving with the shoes pressed hard against it. In other words, broadly speaking, it would seem that the resistance to forward motion offered by a wheel skidding on a rail, may be much less than half that offered by the same wheel while still revolving at full speed, the brakes being in action. This fact was brought out very prominently on Monday and Tuesday. To test the point in another way, a few special experiments were made. Matters are now so arranged in the van that the pressure in the brake cylinder can be determined with the greatest nicety. In the twenty-second experiment the speed of the van being forty miles an hour, the wheels could not be skidded with a pressure of 60 lbs., or 6,000 lbs. on each brake block. But in the twenty-third experiment, although the speed was forty-two miles an hour, the wheels skidded. The speed remaining about the same, the pressure was gradually reduced, but the wheels would not begin to revolve again until it fell to 7 lbs. on the square inch. From this about 2 lbs. must be deducted for the pressure required to overcome the resistance of the spring which takes the brake off, leaving a net pressure of 5 lbs. In other words, although 6,000 lbs. on each block, or 24,000 lbs. for the pair of wheels was required to skid them, 2,000 lbs., or one-twelfth of the amount, sufficed to keep them skidded. It must not be supposed, however, that this represented the diminution of resistance of a skidded as compared to an unskidded pair of wheels; on the contrary, the draw-bar diagram shows that the resistance of the skidded was somewhere about one-third, instead of being only one-twelfth that of the unskidded but braked wheels. The blocks used in this case were of cast iron, 12 in. long. Those used on Tuesday were also of cast iron, but 16 in. long. With these last, in one experiment a pressure of 70 lbs. to the square inch was required to skid the wheels, but only 6 lbs. sufficed to keep them skidded. At a velocity of four miles an hour skidding was produced by a pressure of but 40 lbs. At high velocities, such as fifty to sixty miles an hour, a pressure of less than 90 lbs. would not produce skidding. It is worth notice that, no matter what the speed of the train, a pressure of 6 lbs. to 8 lbs. kept the wheels from revolving. This appears to demolish the theory that at high velocities the coefficient of friction between wheel and rail is less than at low velocities. If this theory were correct, then when the train was running slowly a much greater pressure would be needed to keep the wheels from turning than would suffice at high speeds; but so far as the inquiry has as yet proceeded, not a scrap of direct evidence to this effect has been obtained.

There is but one way of explaining the various anomalies presented by the results of these experiments. They are in a very large proportion due to the inertia and momentum of the wheels. To elucidate this point a little, we give the following figures:—The weight of the brake van is 8 tons 2 cwt. 2 qr., or, with fourteen passengers, nearly 20,400 lbs. These figures are not precisely accurate, but near enough for our purpose at present. About one-half this weight was on the braked wheels, which invariably went first. When the brakes were applied, the springs deflected $\frac{3}{8}$ in., showing an augmentation in weight, the precise amount of which has not yet been calculated, and which was due to

causes which are too obvious to need explanation. We shall assume that the load under these conditions on the braked wheels was 11,000 lbs.; but in order to stop these wheels from revolving at thirty miles an hour, or 44 ft. per second, a pressure of 60 lbs. was required. This represents 6,000 lbs. on each brake block, or 24,000 lbs. in all; but the wheels pressed on the rail with a force of 11,000 lbs., or but eleven-twenty-fourths of the force with which the brakes were applied to the wheels. If the matter ended here, we should be justified in assuming that the coefficient of friction between wheel and rail was more than twice as great as the coefficient of friction between wheel and brake block. But the wheels when once skidded could be kept skidded apparently at any speed, slow or fast, by forcing the brake blocks against them with a force of 6,000 pounds only, or less than half the insistant weight; consequently on this basis we would have reason to assume that the co-efficient of friction between wheel and blocks was much greater than that between wheel and rail. These two assumptions are contradictory, incompatible, and yet each is justified by the experiments. Both assumptions are, however, vitiated by neglecting the mass of the wheel. Before the wheel can be stopped the work stored in it must be taken out of it. Let us represent this by x, and the resistance proper to the co-efficient of friction between wheel and rail by y. Then the duty to be performed by the brake in stopping the revolution of the wheel must equal $x+y$. Again, to put the wheel in motion after it has stopped, y must reproduce x. Let the resistance due to the co-efficient of friction between the wheel and block be represented by z. Then y must equal $x+z$, or the wheels will not begin to revolve with the brake on. We have here purposely omitted all reference to the important part played by time in this matter, as it will suffice for our present purpose to call attention clearly to the fact that momentum and inertia must be taken into consideration. To show how important a part both play in the matter, it will be enough to say that the revolving mass of each wheel of the van is as nearly as may be equal to 450 pounds moving at the speed of the train. Thus at thirty miles an hour, or 44 feet per second, the *vis viva* of each wheel is not less than 13,500 foot-pounds, and to stop such a wheel in one second would require a tangential force of 950 pounds; or assuming the co-efficient of friction between block and tire to be 0.1, then a single block would have to be pressed against the wheel with a force of 9,500 pounds, and this, be it observed, withont taking any account of the friction between rail and wheel tending to keep the latter in motion. In like manner, if the speed be sixty miles an hour, or 88 feet per second, then the *vis viva* of the wheel will be nearly 54,000 foot-pounds or 24 foot-tons; and to stop such a wheel in one second, or 88 feet, would require a force of, in round numbers, 6,000 pounds, or a brake-block pressure of 60,000 pounds. It is hardly necessary to say that no brake exists which will produce skidding under such conditions in one second; and although apparently skidding does take place suddenly and with a jerk, yet it is certain that nothing like instantaneous action ever occurs. Again, when the wheel has been skidded, a force of 6,000 pounds would have to be applied to its circumference to cause it to resume motion at the rate of 88 feet per second within a distance of 88 feet; and it was abundantly proved by observation in the van on Monday and Tuesday, that if the pressure upon the brake is taken off altogether, the wheels will continue to skid for some moments, and that they resume their velocity slowly. It is well known, indeed to engine drivers that tender wheels obstinately refuse to revolve when skidded at high speeds for a quite preceptable time after the brake has been taken off.

It will be seen, then, that the task which Captain Galton has before him is no light one. Certain conclusions, having a direct practical bearing, can be drawn easily enough; but neither Captain Galton nor Mr. Westinghouse is likely to be satisfied with this. The London & Brighton Railway Company have, with the utmost liberality, placed unexampled facilities for making experiments at the disposal of Captain Galton and Mr. Westinghouse, and the latter gentleman has prepared an apparatus which will deal with any brake, air or vacuum. Facts are being obtain-

ed by the hundred, and it rests with Captain Galton to reduce these facts to a condition which will render them extremely valuable to the man of pure science, as well as to the engineer. Nothing, however, can be learned concerning the laws of friction unless the influence of the *vis viva* and inertia of the revolving wheels is carefully calculated for every experiment.

THE RIVER THAMES.

From "Engineering."

The Thames Conservancy and the Metropolitan Board of Works have, during the last twelve months, been placed in diametrical opposition in regard to their views of the cause of the pollution of the Thames, and each Board has published a report casting the blame on the other. These reports have been criticised by engineers, chemists, and others, and the simple result has been that the public have been left in a fog of Egyptian darkness as to whom is due the fact that about 20 miles of the river is rapidly approaching a state equal to, if not physiologically worse, than that which we observed in 1848-49 (cholera years) and in 1855-56, when the Thames was literally no better than a foul stinking ditch. It was from this latter circumstance—the abomination of sanitary desolation—that the main drainage scheme had its origin, and we regret to add in some senses its failure, so far as recent experience goes.

Again, the present year has afforded a repetition of evils that are periodic. For several years past the summer temperature has been comparatively low. During the last month it has been literally tropical, ranging from 75 deg. to 85 deg. Fahr. in the shade. Hence, as we shall presently show, the Thames now presents appearances that cannot be regarded without serious apprehension. If our conclusions be true the condition of the river is at least serious. Of this our readers may, without any pretension to engineering, chemical, or other professional knowledge, easily judge for themselves, and to assist them in so doing the following brief account of the observations, experiments, &c., that have been made, and the mode of conducting them, may be of advantage.

Our observations for the present year were commenced on the 13th of April. On that day the Thames from London Bridge to North Woolwich presented very much the appearance of a farmyard pond. Between Blackwall and Woolwich, the amount of confervoid matter, floating in the river, was so great that its green color could scarcely escape the attention of any one having occasion to pass down the stream. This color of course indicated the presence of an immense amount of vegetable germs in suspension. Subsequently it became evident that the river was loaded with these organisms, and on July 22, when the last of these observations were taken, the water at ebb, from Blackwall to the south shore upward of Purfleet, presented a color of a dark olive-green, with a "sweet" fetid smell common on all the marshes of the Thames and Lea, at the time the weeds, &c., decay, especially during a warm August and September.

As a rule during the three months above mentioned, samples were gathered from Westminster to North Woolwich, and occasionally to Gravesend, as the tide ebbed, so that the end of the low water could be reached at the last station, below London Bridge. None were taken at an interval less than three or four days after a rainfall, it being desirable that the river should be seen in its normal state. Here it may be remarked, that a heavy rainfall, as on June 23rd, entirely destroys what we may call normality of the stream, owing to the large amount of oxygen brought into the river in solution. From neglect of this precaution has arisen the absurd idea that sewage, running for a few miles, becomes oxidised *under all circumstances.* It may, after a heavy rainfall, for reasons already assigned. We haye known for example the Leam, which runs through

Leamington, and shortly below joins the Avon, to be wonderfully improved after a rainfall, which increased the sewage to 1,500,000 gallons per day from 450,000 gallons, the latter quantity being at the time we refer to about the daily average. These and other sources of error were carefully avoided in our examination.

Our space will not permit us to give more than a general summary of the various observations made during this period of three months, but those made on July 22nd may be taken as a normal type. At 9 A.M. to 10 A.M. the river presented an appearance of a dark olive tint mixed with brown, between London Bridge and Blackwall. Between Greenwich and Blackwall there were frequent issues of suspended matter, apparently from the escape of gas from the bed of the river, which produced circular areas of increased suspended matters, so dense as to completely hide from observation the bottom of a glass 3 inches below the surface. Beyond Blackwall to Barking the smell of the water was of that peculiar decomposed vegetable character already alluded to, varied by the stench of nitrous acid and glue or manure preparations from the north bank. This was so offensive as to stir up the attention of some children, who adopted the time-honored plan of keeping the smell from their noses. The wind was N.N.E. At the Crossness outfall of the South London sewage, there was a considerable deposit of sewage matter on the bank, and on the upper part of the bank the green deposit showed signs of vegetable matter arising from the mixture of sea and fresh water.

At this point and eastwards the water in mid-channel was a vegetable green color, with a strong bilge-water smell. A mile below, the stench of some works, dealing with boiling animal matter, was most offensive. A little further below and near Price's wharf was a long sewage deposit; the same occurred near, but west of Erith. Below Erith the water became worse in color in mid-channel, with deposit of sewage matter on the south shore, especially in hollows. At Purfleet the river presented an appearance very commonly to be seen at Dumbarton on the Clyde, where sewage and sea water freely mix. The south shore near Greenhithe presented sewage deposit. Here it may be remarked that a specimen of water taken from mid-channel was perfectly free from sea-salt taste, a fact indicating that the sewage, &c., had, with the ebbing tide, traveled so far on its journey *towards the sea*, but, as we shall see, *not into it*.

At the turn of the tide at Gravesend, about noon, as indicated by a small boat presenting its stem eastwards, samples were taken of the surface water. These could only be compared, as regards suspended matter, with the worst specimens of sewage that might be drawn on ordinary occasions from London sewers. When shaken the suspended matter oscillated in the glass vessel, as if immersed in a viscid fluid, showing signs of the presence of sewage that could not be mistaken by an experienced eye. As the larger vessels (200 tons and upwards) turned stem to sea, fresh samples were taken from shore to mid-channel, with the same result. The water was brackish to the taste, indicating that the outward flow of the sewage to the sea had been arrested, In other words *the metropolitan sewage was being driven back to London*, with the addition of sea-water, which of course makes bad worse.

Here, by way of parenthesis, we may remark (as we have already frequently done) on the danger of mixing sewage with sea-water. We have, in previous volumes, drawn attention to the experiment of Professor Daniell on the effects of mixing land drainage water with sea-water on the coast of Africa, off the Niger, &c., particulars of which will be found in the *Philosophical Magazine* of (we believe) 1840-41. But our readers need not trouble to refer to those works. A walk from Rosherville to a mile beyond Gravesend, or near Hastings, Ryde, Southampton, &c., at places where the sewage runs over the low-water shore, will give sufficient evidence as to the danger that may arise from the mixture of sea-water and sewage. The sulphates of the one and the vegetable and animal matter of the other undergo mutual decomposition, produce sulphuretted hydrogen and air poison. During the next two months many thousands of persons will visit three or four watering-places on the Thames thus situated. One of the most favorite of these resorts has the reputation of possessing about three

acres of cesspools in close proximity to the sea—we mention no names. A word to the wise should be sufficient.

But to resume the thread of our observations. During the last three months samples were taken of the deposit left at low water by the sewage between Westminster Bridge and about two miles below Gravesend. Some singular facts were thus presented. Below Gravesend the mud presents, when wet, a brown appearance, turning to a blue or greyish tint when dry. On analysis, this mud seems to be the product of a gradual and natural lime process of treating sewage. In other words, the bicarbonate of lime held in solution seems to have precipitated portions of the organic matter. Where clay is the most prevalent material of the banks, the precipitate is analogous to the so-called native guano, produced by the A B C process. Another singular fact is that the precipitates have corresponding appearances when wet. The clay precipitate has a peculiar reflective surface, while the lime precipitate has a dull heavy surface, having no reflective power. It is very possible that the Thames possesses, by the varying constituents of its banks and bed, a self-purifying power, but far from equal to the requirements which four million people insist on its performing. But where neither clay nor lime present themselves, no such result can exist, and, consequently, between, say Poplar and Westminster Bridge, the sewage deposit wherever it exists, remains only to decompose, and therefore to poison the air.

The effect of the in-coming tide is remarkable. Taking the date of July 22, the sea-water had reached Crossness at about 6 P.M. Its freshness remained unimpaired up to that point, the sea tint being remarkably evident. But, above Crossness, the freshness was lost. The olive-green tint of the morning's observations was apparent, together with the smell of bilge water. Off Blackwall, the Thames was of a brownish-yellow tint, and at London Bridge at the moment of high-water it was evident that the comparatively stagnant lake, that had been oscillating to and fro, was still as bad as it was ten or twelve hours previously, and the same observation held good as far as Hungerford.

Although we have chosen a special date, because no possible intervening cause could have disadvantageously influenced the observations above related, it must be distinctly understood that precisely similar circumstances occurred during three months, and we may add to some extent for the last three or four past years. We feel therefore compelled to the belief that the conditions of the Thames (within the limits assigned) are as follows:

1. That the metropolitan sewage area of the Thames may be considered as bounded east at a little below Gravesend (perhaps at Sea Reach) with a wall of sea-water, and on the west, at a little above Battersea, by a wall of fresh water.

2. That while neither of the boundaries are exact, they furnish two different results. The sewage may pass, and no doubt does pass far beyond Battersea, but is then diluted with fresh water from the Upper Thames, despite sewage contamination from riparian towns, &c., such as Richmond, Kingston, Isleworth and the like. On the other hand, the eastern boundary supplies, by a flood tide, sea-water which by under currents runs perhaps beyond London Bridge.

3. That for all practical purposes, the sewage cast into the Thames at Barking and Crossness may be considered as located between such boundaries oscillating with the tide; that, meanwhile, in hot weather (80 deg. Fahr. atmospheric temperature) it fosters the growth of sewage fungus, confervoid matter, &c., to which it acts as a manure.

4. That there is a natural process of defecation going on, partly by rainfall, the action of lime and clay, as already pointed out, and the disturbing action of steam and other vessels. But, on the other hand, the fæcal and other matter cast from these vessels into the river may, to a large extent, add to the pollution of this stream.

5. It would appear that whatever endeavors are made at Barking and Crossness to retain suspended matter by the settling tanks, such exertions are practically futile, so far as the physiological conditions of the river are concerned. It is impossible, in the few hours during which settling can take place, that more than a small portion of the suspended

matter can be removed. Referring to experiments made at Leeds it was found that, after a few days, entire settlement of suspended matter was not effected in glass vessels that were never disturbed. But, if we take into account the rush of new sewage into a tank hourly, changes of temperature and a variety of other concomitant circumstances, too numerous to mention, any "settlement" at either Barking or Crossness is simply nominal.

The present state of the Thames has been made the subject of investigation during the last few weeks by Mr. Buckland, with special relation to the interest of the fishermen, and at a lecture that gentleman lately gave, the results of his investigation showed that the loss in a pecuniary point of view to London is very heavy. Some conversations that we have recently had with old fishermen residing at and below Gravesend, lead to the same conclusion. As early as the 12 Richard II a statute was passed enjoining the mayors of boroughs to make proclamations against throwing filth or rubbish into rivers. No communication between the cesspools of the houses and the sewers of the streets was permitted until 1847, and now we find the Thames converted into a kind of running cesspool, in that portion of the metropolis which contains most of its wealth and intelligence.

As we fully anticipated, the Rivers Pollution Prevention Act is practically a dead letter. So far as the metropolis is concerned, the Metropolitan Board is, in the name of the ratepayers, a licensed polluter. Far be it from us to lend the least sanction to some of the wild schemes that have been held out by various companies and individuals to cure these evils. But here we have some undeniable facts. We have a river running through London for a distance of, say, twenty miles, which nominally carries away, but really retains, the sewage of 4,000,000 persons. From its surface there exhale noxious gases, and on its banks equally noxious manufactures are carried on. The Statute Book shows laws against all these evils, but the most interested parties to retain the evils are those who have to put such laws into force. If this is not putting into defiance all common sense and sanitary improvement, we should be at a loss to find another instance. Meanwhile the kings play while the common people perish. The Board of Trade falls out with the Metropolitan Board, the Thames Conservancy with the latter, the Courts of Chancery are afraid to stir, and "grant time," and thus, year after year, matters progress nominally, while if we take the veil off the sight, we find ourselves gradually walking backwards, or, to use more modern and political phraseology, in a state of retrocession to conditions that were abominated twenty years ago.

THE CONSERVANCY OF RIVERS AND STREAMS.

By EDWARD EASTON, Esq., President of the Section of Mechanical Science.

Paper read before Section G of the British Association—Dublin Meeting.

By the conservancy of rivers and streams I mean the treatment and regulation of all the water that falls on these islands from its first arrival in the shape of rain and dew to its final disappearance in the ocean.

I had at first, in my ignorance, contemplated treating the subject in a still wider manner by referring to the rivers and streams of other countries; but I soon found that, without going beyond our own, the vast extent of the field to be traversed would make it extremely unlikely that I could, with any satisfactory result, attempt even the more restricted task which I have now before me.

The question of conservancy of rivers and streams involves the consideration of their regulation for the following principal purposes:

1. For the supply of pure and wholesome water for the domestic and sanitary wants of the population.

2. For the supply of water of proper quality and sufficient quantity for industrial purposes.

3. For the proper development of water power.

4. For the drainage and irrigation of land.

5. For navigation and commerce.

6. For the preservation of fish.

In the early days of the world's history there were attempts made to regulate and control the waters of rivers—some of them devoted to military and dynastic objects, but the majority to generally useful ends. Herodotus, speaking of Semiramis, who lived some 2000 years B. C., tells us that she raised certain embankments, well worthy of inspection, in the plain near Babylon, to control the River Euphrates, which till then used to overflow and flood the whole country round about. He also mentions a lady, who lived at a still earlier period, who altered the course of the same river, as a defence against the Medes, to such an extent that, "whereas the River Euphrates ran formerly with a straight course to Babylon, Nitocris, by certain excavations which she made at some distance up the stream, rendered it so winding that it comes three several times within sight of the same village" (Ardericca, in Assyria). "She also made an embankment along each side of the Euphrates, wonderful both for breadth and height, and dug a basin for a lake a great way above Babylon, close alongside of the stream, which basin was sunk everywhere to the point at which they came to water, and was of such breadth that its whole circuit measured 420 stadii (more than 50 miles). The soil dug out of this basin was used in the embankments along the water side. When the excavation was finished she had stones brought, and bordered with them the entire margin of the reservoir. These two things were done—the river made to wind, and the lake excavated—that the stream might be slacker by reason of the number of curves and the voyage rendered circuitous, and that at the end of the journey it might be necessary to skirt the lake, and so make a long round. All these works were on the side of Babylon where the passes lay, and the roads into Media were the straightest; and the aim of Nitocris in making them was to prevent the Medes from holding intercourse with the Babylonians, and so to keep them in ignorance of her affairs." The same energetic princess made brick embankments and quays, and a bridge over the Euphrates, and to do this she turned the entire stream of the river into an artificial cutting, the natural channel being left temporarily dry until the bridge was finished, when the Euphrates was allowed to flow into its ancient bed. It was into this very cutting that Cyrus directed the course of the Euphrates when he took Babylon, 538 B. C. In the time of Herodotus himself, about B. C., 450, there were embankments to the river at Babylon; for he says, "the city wall is brought down on both sides to the edge of the stream; thence from the corners of the wall there is carried along each bank of the river a fence of burnt bricks, with low brazen gates opening on the water."

The same historian, in his second book, describes the hydraulic works of the first king of Egypt, Men or Menes, which were not only gigantic in themselves, but productive of the most important results to the inhabitants of his kingdom. "Before his time," Herodotus says, "the river flowed entirely along the sandy range of hills which skirt Egypt on the west side. He, however, by banking up the river at the bend which forms about 100 furlongs south of Memphis, laid the ancient channel dry, and dug a new course for the stream half way between the two lines of hills.

Passing to Greece, perhaps the most wonderful instance of the successful regulation of water is to be found in the subterranean channels (the modern Greek Katabothra) by which the waters of the River Cephius are carried through Lake Topolias (the ancient Copias) into the sea. These tunnels, which are partly natural and partly artificial, have always served to prevent the lake overflowing the adjoining country.

The well-known tunnel, or emissarium, from the Alban Lake is an example of Roman work. This tunnel, of a man's height, and cut through 6000 feet of lava, is said to have been begun in obedience to the Delphic oracle in the sixth year of the siege of Veii, B. C. 398. By it, the over-flow of the lake which used periodically to flood the Campagna was

prevented, and the waters were conducted through it in an even flow for the irrigation of the fields which it had formerly laid waste. Three vertical shafts and one made in an oblique direction still remain; the marks on the hard rock show that the chisels employed in the cutting were an inch in width. Another Roman work of still greater importance was the emissarium at Lake Fucino, planned by Julius Cæsar and carried into execution by Claudius. This was a tunnel three miles in length, extending from the lake to the River Liris (the modern Garigliano), one mile of it being driven through a mountain of cornelian rising 3000 feet above the lake. It employed 30,000 men for eleven years. There are many perpendicular shafts for raising the rock to the surface and lateral galleries for disposing of the spoil, so as to enable this large number of men to work without interfering with each other.

The supply of water to different cities of the ancients has been the motive for the execution of the most stupendous works, which are almost numberless. It will be sufficient for me to allude to the works constructed for the supply of the city of Samos, about the time of Polycrates, B. C. 530, in which case a tunnel was driven through a hill 150 fathoms high for a length of 7 furlongs. Its height and width were each 8 feet, and it conveyed the water from the River Ampelus into the city. Herodotus tells us that the architect was Eupalinus, the son of Naustrophus, a Megarian. Sir George Wilkinson, in a note on the text, mentions the fact that a French traveler, M. Guérin, discovered one mouth of this tunnel to the north-west of the harbor of Samos, and cleared it from sand and stones to a distance of 540 paces.

It is sometimes asserted that the ancients were ignorant of the hydrostatic law that water finds its own level. This is not the case. Frontinus, who preceded Agricola, the father-in-law of Tacitus, as Governor of Britain, and who was Curator Aquarum in Rome under Nerva and Trajan, mentions in his book, "De Aquaeductibus Urbis Romae," that in case of the fracture of an aqueduct, the water could be dammed up at each side of the point of fracture, and carried over the intervening space in leaden pipes. A great deal of the internal distribution of the water in Rome was managed by leaden pipes under pressure.

The aqueduct which Herod is said to have constructed for the supply of Jerusalem crossed a deep valley—near Rachel's Tomb—by means of a stone pipe working under pressure. This work has been fully described by Mr. Telford Macneill in the report made by Sir John Macneill to the committee for supplying Jerusalem with water. The construction of the pipe is so remarkable that I shall give Mr. Macneill's description in detail. It consists of great blocks of stone through which holes 15 inches in diameter have been cut. One end of each block has been hollowed out to a depth of 4½ inches, with a diameter of 24 inches, thus leaving a recess 4½ inches wide to form the socket of the pipe. The other end has a projection of a size to fit a similar socket in the pipe which lies next to it. This answers to the spigot a modern cast-iron water-pipe. Both socket and spigot are ground, so as to fit with great accuracy, and the joint is made with cement, which has set as hard as the stone itself. The whole line of these stone pipes is surrounded with rubble masonry. The pressure on the center of this very remarkable inverted siphon is not less than 70 lbs. per square inch.

The Arabs at a later period not only knew of this law, but also understood the operation of what we engineers call the "hydraulic mean gradient." The aqueducts constructed by them for supplying Constantinople with water have been very fully described in the most interesting "Letters from Turkey," written by Field-Marshal von Moltke in the years 1835 to 1839. He says that the Arabs knew that water under pressure reaches its own level (*seich gleich stellt*), for they conveyed the water across the valleys in leaden pipes. They had found by experience that the friction through the aqueduct was lessened if openings were made in the course of the line of pipes; and along hill-sides and in places where the pipes are not in deep cuttings, funnel-shaped shafts or wells are made, which acted as air-holes. But in crossing deep valleys, where, of course, no such holes could be made, they built stone pyramids, called "Suterasi," or

water-balances, on the top of which they placed small basins, into and out of which the water was conducted by a leaden pipe laid up on one side of the pyramid and down the other. The level of these basins was so arranged that they were at an inclination rather greater than the average fall of the aqueduct; and thus they allowed the water to take the hydraulic mean gradient due to the head necessary for the delivery of the water. It is probable that these "suterasi" were made about 1000 A. D.

In Britain the Romans without doubt constructed embankments for the control of rivers, but for at least 1000 years after their time very little was done in the way of great public works of this description ; and it was not until the beginning of the sixteenth century that the state of the rivers in Italy commanded the attention of the great land-owners and scientific men of that country. At that time, chiefly in consequence of the appointment of a Commission in 1516 by Francis I, works for remedying existing evils were seriously thought of : and for a long series of years the most eminent mathematicians and engineers were engaged in investigating the subject and in designing and carrying out works of greater or less magnitude. A very full collection, both of the writings of these Italian engineers and of the descriptions of their works, is contained in a book of thirteen volumes, published at Bologna, in 1821-24, entitled "Raccolta d'Autori Italiani che trattano del Moto dell'Acque." It would seem that about the same time the question began to excite interest in England, for it was in the reign of Henry VIII, that a public statute first dealt with river conservancy. But it is to be remarked that neither in Italy nor in England was the question treated in anything like an exhaustive manner. The great hydraulic works of Italy relate almost exclusively to irrigation and navigation, whilst the drainage of lands and the prevention of floods were the objects of legislation in England. During the same period the Dutch were of course constructing many important hydraulic works; but these, from the special circumstances of the country, were not such as to have much bearing on the general question of the conservancy of rivers.

After the drainage of the Fens, the next great works in England were the canals, which, in a very few years, extended over the whole of England, and formed a complete system for the conveyance of traffic. It is superfluous to say that their construction and maintenance had a strong bearing upon the regulation of rivers. The well-known saying of Brindley that rivers were "principally valuable for feeding canals" sufficiently indicates the subserviency of the other interests involved. Next the introduction of railways and steamboats, and the increase in the size of ships, turned the attention of those interested in rivers to the improvement of the tidal harbors and channels ; and from that time to the present the greatest hydraulic works of our time have been connected with navigation. The concurrent increase in manufactures necessitated the employment of water in ways apparently antagonistic to other interests, and introduced the new element of pollution of our rivers and streams, whilst the demands of sanitary legislation, consequent on the great increase of population, made it imperatively necessary that their purity should be maintained. Indeed, we may say that the present high state of civilization in which we live has involved greater complications in this as in other departments of life, and requires special arrangements to meet them.

Legal enactments for the regulation of rivers, and for defining the rights of property in water, have existed from very early times. Solon laid down that to intercept the supply or to corrupt the quality of water is a crime. He also enacted that if any one dug a well to a depth of ten fathoms (ὀργυῖαι) without finding water, he should be permitted to take from his neighbor's well a pitcher of six χόες (about 18 quarts) twice a day. Plato, in his Laws, mentions an analogous provision, but confines it to drinking water only. Another law quoted by him is more to the point; it runs as follows : "If after heavy rains any of the lower riparian proprietors should injure a neighbor who lives above them, by stopping the downward flow of the water, or in case, on the other hand, the proprietor living higher up shall injure his neighbor below, by negligently allowing the water to run down upon him, either of them may call in the magis-

trates and obtain a decision for the guidance of both parties. If either party fail to abide by such decision, he shall be punished for the enviousness and peevishness of his spirit, and shall pay double damages to the injured person."

The Pandects of Justinian, which are a collection of all the old legal authorities of Roman law, analogous to our own reported cases, contain a variety of leading principles which govern the administration of the law of running water: principles identical mainly with that of our own common law. Some of these related to fishing, watering cattle, to the interruption of navigation of lakes, canals, and ponds, to the preservation of the water supply, to the repairs of river banks, and to the regulation of the summer and winter flow of what are termed public rivers. It was enacted among other things, that nothing should be done to the stream or banks of a public river, whereby the flow should be altered from its state in the preceding summer.

The earliest record in our own statute law of any enactment relating to rivers is that contained in 25 Edward III, c. 4, which legalized all "gorces, mills, wears, stanks, stakes and kiddles," of a date previous to "the reign of his grandfather Edward I, by which the common passage de neefs et batelx en les grantz rivers d'Engleterre be oftentimes annoyed," and ordered the immediate pulling down of all such erections which were of a later date.

From that time, until the enactment of Henry VIII, there were various laws passed, chiefly relating to the navigations and rights of mills, and occasionally to the preservation of fish. After Henry VIII, very many private acts and charters granting powers for the drainage and reclamation of lands, for improvement of navigation, and matters of a similar kind, were passed from time to time. A great number also of royal commissions and select committees have conducted inquiries, and made reports upon most of the various branches of the subject, *e. g.* the pollution of rivers, the water supply, arterial drainage, navigation, fisheries, &c., but until the appointment last year of the Select Committee presided over by the Duke of Richmond, no attempt, as far as I am aware, has been made to grapple with the question as a whole, and the report made by them to the House of Lords omitted to deal with, at least, two of the objects I have indicated as being necessary to the proper consideration of the subject.

The recommendations made in the report of that Committee were most important, and they will, if carried out, remove many of the difficulties which stand in the way of a complete system of conservancy of our rivers.

So much has been written on the engineering details of this subject, by men far better qualified than I am to deal with them, that I shall confine myself to the simple statement of the principles which have been recognized by the chief authorities as essential, and to a few suggestions, which my own experience leads me to think may be of some value. Almost all the great engineers of former generations, who have paid attention to this question, Smeaton, Telford, Rennie, Golborne, Mylne, Walker, Rendel, Stephenson, Jessop, Chapman, Beardmore, and without mentioning names, many of the most eminent now living, have agreed to the following general propositions:

That the freer the admission of the tidal water, the better adapted is the river for all purposes, whether of navigation, drainage, or fisheries.

That its sectional area and inclination should be made to suit the required carrying power of the river throughout its entire length, both for the ordinary flow of the water, and for floods.

That the downward flow of the upland water should be equalized as much as possible throughout the entire year; and

That all abnormal contaminations should be removed from the streams.

In carrying out these principles, it is perhaps superfluous to say, that modifications must be introduced to suit the particular phenomena of each river. In some watershed areas, it would be easy to construct reservoirs, which would to a great extent equalize the flow and reduce floods. In others it might be better to control the floods by means of embankments. In others, to have weirs, and sluices, delivering into side channels, parallel to the main stream, with the same object. Sometimes reservoirs or receptacles, must be made for catching the débris brought down by the streams. In fact, every river must be treated as a

separate entity. It is therefore necessary that a systematic collection of data, relating to rainfall, the geological character of the gathering ground, and the volume of each separate stream, should be made for each watershed area; and this should be carried on for a sufficient length of time to enable a fairly correct estimate to be formed of the behavior of the river both in time of flood and in time of drought. The establishment of self-acting tide-registering gauges at several points of every outfall should be insisted on. By these means the whole of the phenomena of a watershed area could be ascertained and recorded, and safe and trustworthy knowledge could be obtained, which would contribute towards the determination, not only of the works which ought to be executed, but of the incidence of the taxation by which the necessary funds should be raised. For instance, it is obvious that where the geological character of a watershed is variable, one portion of it consisting of a permeable stratum, such as chalk or red sandstone, and another portion of an impervious stratum, such as the tertiary clays or the shales of the millstone grit, the same works would not be adapted to each section of the river, nor would it be fair to charge all the expense according to the same scale of contribution. The former, that is the permeable stratum, is not only, from its absorbent nature, not the cause of floods, but is, by reason of that characteristic, absolutely constituted by nature one of the very works which must be devised by art to mitigate the effects of rainfall on the latter, or impervious stratum.

Bearing this in mind, I have often thought that nature might be usefully imitated in this operation, by passing the surplus rainfall into the permeable strata of the earth by means of wells, or shafts, sunk through the impermeable strata overlying them. This has been done in isolated cases for the drainage of lands, but not for the deliberate purpose of preventing floods and equalizing the flow of rivers.

I also wish to remark that artificial compensating reservoirs may be much more frequently made use of than is generally supposed to be possible, when it is considered that, so long as the dams are constructed in situations where there is no danger of their giving away, it is by no means necessary that they should be water-tight, and that, therefore, they can be constructed at a very much smaller outlay. In fact, the purpose would be answered by a series of open weirs, which would collect the water in times of flood and discharge it gradually down the stream.

The example of our French neighbors in the more general use they make of movable weirs—*barrages*—of various constructions could, I am satisfied, be followed by us with very great advantage in many cases.

The question of water power is one which, I think, deserves more consideration than it has lately received. It has been the fashion to consider that small water mills are of little or no value, and, in the present state of most rivers and streams, this is to a very great extent true, but only because the supply of water to work them is so variable and uncertain. Sufficient attention has never yet been given to the subject of the amount of compensation water which should be given for the use of riparian proprietors, when the watershed areas are dealt with for purposes of water supply. There is a kind of empirical rule acknowledged by most of the eminent water engineers, that one-third of the average flow of three consecutive dry years is a fair equivalent for the abstraction of the water falling on a gathering ground. I am strongly of the opinion that, looking to imperial interests, advantage should be taken of every opportunity of dealing with a gathering ground to provide for a much larger proportion of its available water being sent down the streams, so that the natural water power of the country may be properly developed. The extra cost of the necessary works must, as a matter of course, be borne rateably by the interests benefited. It is certain that with the progress of invention many more ways of utilizing this power will be discovered. At present, through the medium of compressed air, of hydraulic pressure, and of electro-motors, the great disadvantage of its being only available at the spot where the water runs is overcome, and the power can be transmitted to any distance, and used wherever it may be most conveniently applied.

Sir Robert Kane, in his most valuable and exhaustive work on the "Industrial Resources of Ireland," has given an estimate of the value of the power allowed to escape every year in the shape of floods, and the same calculation might be applied to the sister kingdom. It is probably no exaggeration to say that where running streams exist the power required for estate purposes, on the majority of properties in the United Kingdom, might be obtained by a proper conservation of the natural water resources of those streams.

The consideration I have been able to give this subject, has helped to convince me that, although a vast amount of labor and research has been devoted to it, it is nevertheless one in which "a more systematic direction to scientific inquiry" is urgently needed.

A vast collection of scientific facts exists, but they require arrangement and collation, and future observations should be more strictly classified, so that the bearing of each one, both on the others and on the subject at large, may be properly appreciated with a view to a practical result.

In France this is being done to a very large extent, and an excellent map showing the phenomena of the rivers and streams of that country is now in course of preparation. For many years also very accurate observations of the phenomena of the whole of the basin of the Seine have been taken, and have been centralised (*centralisées*) by that eminent engineer, whose loss, all who had the privilege of knowing him, either in his work or in private intercourse, are deploring, M. Belgrand, late Inspector-General of the Ponts et Chaussées, and by his able coadjutor, M. M. G. Lemoine. These observations have been published in the form of diagrams, admirable in their simplicity of design, which show at a glance the bearing of every one of those phenomena on the general character of that river.

In Italy also, where there exists a distinct department having control of the hydraulic works of that country, the same exhaustive system of collation and record has been followed, and the results have been published in a series of Tables. In Germany, although the same complete system is not in vogue, its chief river has been the subject of most thorough investigation, the results of which have been published in a beautiful map of the Rhine and its regulating works.

In our own country, as might be expected from the number of engineering works which have been executed, there probably exists an amount of detailed information on special and often minute points which is unsurpassed and, probably, unequalled in the world.

But, although as I have said before, a great number of eminent men have treated in an exhaustive manner the phenomena relating to many of the principal rivers of Great Britain and Ireland; yet, as far as I am aware, there has been no attempt to collect and combine these most valuable, though detached fragments of knowledge, so that their relation to one another might be seen, and a general conclusion arrived at. This can only be done by the establishment of a public department analogous to those described as already existing in France and Italy.

I do not wish to be understood that, in suggesting the collection of additional data relating to the phenomena of rivers, I am advocating delay in dealing with the existing state of things until the facts have all been ascertained. On the contrary, I believe that the first step ought to be the establishment of a distinct water department, which should at once address itself to the remedying of the evils which are found to be most pressing. The time has long since arrived when the present neglected state of many of our most important streams should be dealt with, and that this was also the conviction of Parliament and of the Government is evident, from the appointment of so influential a committee as that presided over by the Duke of Richmond last session.

Even the imperfect sketch which I have been able to place before you will have made manifest, I think, the enormous importance of the subject and of the interests involved—interests subject to periodical losses arising from the present imperfect organization, or I may say, the present entire want of organization—losses which are not only monetary, and therefore to a certain extent capable of being estimated, but which affect health and imperil life, and on that

account, as is the unhappy experience of the highest as well as the lowest of the community, utterly incapable of appreciation. How, for instance, can we estimate the loss sustained by the country at large by the premature death of that noble-minded and accomplished gentleman, the Prince Consort, whose life and energies were devoted to the encouragement of all the objects which this Association is established to foster and promote, and who showed his strong sense of its usefulness by presiding at one of its most brilliant meetings.

When it is considered that many lives are annually sacrificed, either directly by the action of floods, or by the indirect but no less fatal influence of imperfect drainage—when it is remembered that a heavy flood, such as that of last year, or that of the summer of 1875, entailed a monetary loss of several millions sterling in the three kingdoms—that during every year a quantity of water flows to waste, representing an available motive power worth certainly not less than some hundreds of thousands of pounds—that there is a constant annual expenditure of enormous amount for removing débris from navigable channels, the accumulation of which could be mainly, if not entirely prevented, that the supply of food to our rapidly growing population, dependent, as it is at present, upon sources outside the country, would be enormously increased by an adequate protection of the fisheries—that the same supply would be further greatly increased by the extra production of the land when increased facilities for drainage are afforded—that, above all, the problem of our national water supply, to which public attention has of late been drawn by H.R.H. the Prince of Wales, requires for its solution investigations of the widest possible nature, I believe it will be allowed, that the question, as a whole, of the management of rivers is of sufficient importance to make it worthy of being dealt with by new laws to be framed in its exclusive behalf.

A new department should be created —one not only endowed with powers analogous to those of the Local Government Board, but charged with the duty of collecting and digesting for use all the facts and knowledge necessary for a due comprehension and satisfactory dealing with every river basin, or watershed area in the United Kingdom—a department which should be presided over, if not by a Cabinet Minister, at all events by a member of the Government who can be appealed to in Parliament.

The department should have entire charge of, and control over, all estuaries and navigable channels, both because these are used by foreign vessels, and therefore the responsibilities attaching to their preservation are international, and because they must be protected from hostile attack, and on these accounts are essentially imperial property. For the same reason the cost of amending and maintaining them should be defrayed out of the Imperial exchequer.

As regards the regulation of the remainder of the water-shed area, the conclusions arrived at in the report of the Duke of Richmond's Select Committee seem to me entirely satisfactory. I cannot do better than give a few extracts from that report. The Committee say—"That in order to secure uniformity and completeness of action, each catchment area should, as a general rule, be placed under a single body of conservators, who should be responsible for maintaining the river from its source to its outfall in an efficient state. With regard, however, to tributary streams, the care of these might be entrusted to district committees, acting under the general direction of the conservators; but near the point of junction with the principal stream they should be under the direct management of the conservators of the main channel, who should be a representative body constituted of residents and owners of property within the whole area of the watershed." The committee go on to say that "means should be taken to insure the appointment of a Conservancy Board for each watershed area," but that application should first be made by persons interested in the district, and that then the departmental authorities should send inspectors to make local inquiries and to report upon the "necessities and capacities of the district, and suggest the area and proportions of taxation."

The scheme with such modifications as may be deemed necessary is then to be embodied in a provisional order to be submitted to Parliament for confirmation. It will be seen that this mode of

procedure is precisely analogous to that of the Local Government Board in relation to public health—a procedure which, as I am able to state from practical knowledge, works admirably in most cases. The committee further recommend that the provisions in any local or other acts which would interfere with the proposed scheme, should be repealed. They are also of opinion that "the Conservancy Boards should be enabled to execute the powers conferred on local authorities by the Rivers Pollution and Prevention Act." It will also be necessary that their powers should extend to the carrying out of any acts passed or to be passed for the protection of the fisheries.

With regard to what is probably the most important point of all, the finding of the money necessary to carry out these recommendations, the committee advocate the introduction of a new principle of taxation, the soundness of which cannot be questioned. Instead of the principle first introduced by the statute of Henry VIII, and observed ever since, of levying taxes in proportion to the direct benefit conferred, the committee propose that the rates should be distributed over the whole area of a watershed, including not only the lands, but the towns, and houses, and all other property situate within that area. This is in fact no more than a general application of the law of highways, which in the time of the Romans, according to Justinian, applied equally to waterways. It is perfectly just that every acre, the drainage of which contributes to the flow of the streams and rivers and of every watershed area, should in some proportion or other, contribute also to the cost of maintaining the channels of those streams and rivers in an efficient state. The incidence of the taxation must of course, as has been pointed out, be determined by the circumstances of each particular case, but there is no doubt that the conclusion of the Duke of Richmond's committee, that "the taxation should be levied on the basis of rateable value," is the only sound, and at the same time practical way of dealing with this difficulty.

The word "taxation" is not, I fear, generally connected with any idea of profit to the individual taxpayer. But in this case, as I hope in the course of this address I have made clear, it is probable that the prevention of large present losses, and the advantages gained by an improved system, will give not only a fair but an ample return on the capital expended.

It is my firm belief that an intelligent management of watershed areas would be compatible with an absolute profit to every interest affected; that we have here no question of give and take, but that in this, as in every other case, the laws of nature, under proper and scientific regulation, can be made subservient to the needs of the highest civilization.

BRICKS AND BRICKMAKING.

From "The Builder."

The science of agriculture no doubt afforded the earliest scope for the exercise of human skill and industry. The Biblical narrative speaks of Abel as a "keeper of sheep," and of Cain as a "tiller of the ground." An application to the mechanical industries allied with arts of construction must, however, have been very early forced upon man, in order to supply implements of husbandry and to provide places of habitation. We read in the fourth chapter of Genesis that Tubal-cain was "an instructor of every artificer in brass and iron," or, according to Gesenius, "a sharpener of every kind of brazen and iron instrument"; a reference clearly pointing to the manufacture of tools required for the purposes of the husbandman and probably of others used in connection with constructive art, then in its rudest infancy.

There is little doubt that clay, in combination with such materials as would bind it together in a compact mass, was employed in the structure of the primi-

tive human dwelling. In course of time this method of construction was superseded by the use of the same plastic substance, moulded, either with or without other ingredients, into suitable forms, which were afterwards dried or burned, the result being the production of the article now known as "brick." The descendants of Noah are described in Genesis xi. 3 (2247 B.C.) as making bricks and burning them thoroughly, afterwards laying them with "slime,"—or, as some translators read, "bitumen,"—in the place of the mortar now employed for the same purpose. With the bricks thus made they built the tower of Babel "on a plain in the land of Shinar." Some of the best authorities agree in regarding the ruins still standing at Birs-Nimrud, to the south-west of Hillah, near the Euphrates, as being the remains of this tower; and it is a remarkable fact that, after the lapse of ages, the bricks of which it is constructed are so firmly embedded in the bitumen used as mortar that it is no easy task to detach or extract one. The circumference of the tower measures 762 yards, and a conical elevation on the western side rises to the height of 198 feet. The various stages of brickwork are of different colors,—a result which must have been attained by some special process, the ordinary Mesopotamian brick being of a pale yellow or whitish colour. The late Mr. George Smith, the indefatigable Assyrian explorer, deciphered among the tablets in the British Museum a history of the building of this tower, which will be found in his "Chaldean Account of Genesis."

The mounds of Assyria and Babylonia abound with bricks, sun-dried and burnt, Rawlinson, Layard, Mignan, Rennel, and other travelers having found them in incalculable quantity. Modern research has also confirmed the statement of Herodotus, that from the clay thrown out of the trench surrounding the ancient Babylon, bricks were made and burnt, which were used in building the massive walls of the city. The buried palace of Nebuchadnezzar on the Euphrates is said to have furnished bricks for the erection of all the buildings in its neighborhood for many years past; and we are told that "there is scarcely a house in Hillah which is not almost entirely built with them." Muller, in his "Science of Language," says that the ancient materials from the colossal palaces erected by the great ruler of Babylon were carried away for building new cities, and that Sir Henry Rawlinson discovered numbers of the bricks in the walls of the modern Bagdad on the borders of the Tigris. No doubt can exist as to their identity, owing to the custom which prevailed in Assyria and Babylonia of marking each brick with the name and title of the king in whose reign it was made, and also, in many instances, with the name of the place in the construction of which the brick was to be used. These inscriptions are in cuneiform characters, and were impressed upon the brick in a sunken rectangular panel, closely resembling that in which the name and trade-mark of modern manufacturers of moulded bricks now appears. From the presence of these inscriptions Sir Henry Rawlinson has been able to ascribe the manufacture of some of the bricks found by him to the period of the older kings of Babylon, who reigned about 2000 B.C. In form, the ancient Assyrian bricks closely resemble thick tiles, being generally from 12½ inches to 14½ inches square, and about 4 inches in thickness. They were almost universally shaped in a mould, some being rounded at the corners for quoins or special work. Generally speaking, they were of a pale yellow or red color. At Kouyunjik, Nimroud, and other places, however, bricks have been found glazed with a thick coating of different colors, some having subjects traced in outline upon them. The walls of the city of Nineveh are said to have been built with glazed bricks of this description, and those of the Median Ecbatana were constructed of colored bricks. Enameled bricks, brightly colored, have also been found in abundance in the mound of the Mujellibeh in Mesopotamia, the principal tints being a very brilliant blue, a deep yellow, red, white, and black.

In Egypt, bricks were used at a very early date, some of the most ancient Pyramids, built at least 2,000 B.C., being constructed of brickwork. The mud of the Nile has always been the sole material employed in the manufacture of Egyptian bricks, and the process at the present day is almost identical with that

adopted in the time of Thothmes III, the prince who is believed to have occupied the Egyptian throne at the period of the exodus of the Hebrews, about 1430 B.C. Brickmaking, there is reason to believe, was a royal monopoly in Egypt, and the bricks which have been found bearing the stamp of Thothmes III, are more numerous than those of any other monarch. Nearly all Egyptian bricks, both ancient and modern, are *adobe*, or sun-dried. A few burnt bricks have been found in river walls or hydraulic works, but their use was evidently very limited. Owing to the rich alluvial character of the mud of which the bricks are made, chopped straw or reeds, pieces of pottery, and other materials, are almost invariably used for the purpose of binding the clay together. The modern process is to form a trough or bed, into which mud and water are thrown, together with large quantities of cut straw. The mixture is tramped into a mortar, taken out in lumps, and then shaped, either by hand or in moulds, into the required forms. A painting discovered upon the walls of one of the tombs at Thebes, in which the processes employed in manufacturing bricks are represented with striking minuteness of detail, shows how closely these resemble the method still adopted in Egypt. Some of the workers are depicted as engaged in digging the mud, and mixing it in heaps with sand, while others carry the material thus prepared in baskets to the brickmaker, who is seen shaping it in the mould. Others, again, are employed either in laying out the bricks thus formed upon the ground to dry in the sun, or in bringing from the river, in jars upon their shoulders, the water required for tempering purposes. Laborers, too, are busily engaged in removing the dried bricks upon flat boards, two of these being slung by ropes attached to each end of a yoke placed across the shoulders. Taskmasters are also shown, watching over and directing the operations, stick in hand, ready to inflict summary punishment on the idle or the refractory. Brickmaking, it must be remembered, was regarded in Egypt as a degrading task, and was usually assigned to slaves. It formed the principal occupation of the Israelites during their bondage in Egypt, after the death of Joseph, and the grievous addition to their toil necessitated by the obligation to provide their own straw may be readily estimated from what has been already said as to the process of manufacture. The bricks made by them during their captivity were probably used in the erection of the great treasure-cities of Pithom and Rameses. At a later date, we read of the erection in Egypt of a brick pyramid by Asychis, the monarch whose reign immediately preceded that of Sethos, the contemporary of Sennacherib and Tirhakah, about 700 B.C. This would probably be one of the four brick pyramids still remaining in Lower Egypt in addition to those at Thebes. Two of these are close to the ancient Memphis and the modern Dashour, and the others are situated at the mouth of the Fyoom. They are built of sun-dried bricks, the chambers having arched ceilings. Brick arches are to be found, however, in buildings at Thebes of a much earlier date, the arch having been invented and used in Upper Egypt centuries before the reign of Asychis. The ordinary Egyptian brick approached somewhat to the modern type, being generally from 14½ inches to 16 inches wide, and of a thickness varying from 5 inches to 7 inches. In the older pyramids they were of an exceptional size, measuring in some cases 20 inches in length, and about 8 inches in width. The bricks of Egypt, like those of Assyria, bore the name of the kings in whose reign they were manufactured, but, in place of being inscribed, they were stamped, the hieroglyphs being in relief.

In Palestine, in the time of the prophet Isaiah, it is clear that bricks were used in the construction of private dwellings (Isaiah ix. 10), and one of the offenses laid to the charge of the people of Israel by the prophet was that of using brick in place of stone, for the construction of their altars (Isaiah lxv. 3).

Amongst the ancient Greeks, who devoted special attention to every branch of constructive art, the manufacture of bricks was placed under legal supervision and brought to a very high perfection. Pliny mentions three distinct varieties as being in general use, and alludes to the circumstance that the walls of the city of Athens, on the side towards Mount Hymettus, were built of brick. Many

of the principal public edifices in the leading cities of Greece were also of brickwork,—perpendicular walls of this construction being considered by the Greek architects more durable than those of stone.

Brickmaking was a flourishing industry in the Roman Empire, both sun-dried bricks (*lateræ crudi*) and kiln-burnt bricks (*lateræ cocti*) being extensively used in public buildings. All the great existing ruins of ancient Rome are of brick, and there is scarcely a province of the once mighty empire which does not still exhibit striking proofs of the durability of the bricks manufactured, and the skill of the artificers who laid them, in the days when Rome was mistress of the world. In the erection of the Coliseum, 80,000 captive Jews were employed, who probably helped to make the bricks of which the noble structure was built, as well as to lay them. The use of bricks in the construction of the public edifices of Rome was indeed so general as to afford occasion for the remark of the Emperor Augustus, with reference to the numerous and extensive architectural improvements he had carried out, that "having found the city brick, he had left it marble." To enumerate all the great public buildings which thus bear witness to the excellence attained by the Romans in the art of brickmaking would be tedious. Among the most notable, as illustrating the progress made at different stages of the history of the empire, are the Pillar of Trajan, the Bath of Titus (A.D. 70), and the Bath of Caracalla (A.D. 212). Notwithstanding this very general employment of bricks in the construction of public edifices, it may be inferred, from the observations of Pliny, that they were not commonly used in private houses, in the building of which wood was probably the chief material; a view which would seem to be, to some extent, confirmed by the extent and destructiveness of fires which occurred in ancient Rome. Pliny, after referring to the common use of bricks by the Greeks, condemns them as wholly unsuited for Roman dwellings, in which party walls were not allowed to exceed 18 inches in thickness, and that thickness he declares, "would not support more than a single story." At this period, the Roman bricks varied considerably in size, but were chiefly of three clases. The largest, known as the Lydian, were 1 foot 6 inches in length by 1 foot in breadth, and the others, which were respectively four and five palms in length, took their titles from their admeasurement. They were all very much thinner than the modern brick, more especially those employed as a bond in Roman rubble-constructions, which, in this respect, bore a close resemblance to the wall-tiles of the present day. The kiln-burnt bricks in the Greek building at Treves called the Palace of Constantine, are all "of a square form, 3 inches in diameter, and $1\frac{1}{4}$ inches thick." The custom of marking each brick, which has been alluded to as prevailing amongst the Assyrians and Egyptians, was maintained by the Romans, the various brickmakers having each their distinguishing mark. Every brick was stamped with the figure of some god, plant, or other symbol, encircled with the name of the maker, the consulate, and the legion by which it was used. The Twenty-second Legion has been traced through Germany by bricks which bear its name, and at Caerleon, in England, Roman bricks have been discovered with the inscription "Leg. II, Aug.," while others found at York attest the presence there of the Sixth and Ninth Legions. Some of these bricks were scratched on the surface, while others had lumps raised on them, or were deeply notched, with the view of making the mortar adhere more firmly. The Romans preferred, for brickmaking purposes, a clay which was either of a whitish hue or decidedly red. They considered Spring the best time for carrying on the process of manufacture, and it was the general custom to keep bricks two years in stock before laying them.

With the decadence of the Roman Empire, the art of brickmaking declined and fell into disuse, but, after a few centuries, experienced a complete revival, the Italian ecclesiastical and palatial architecture of the Middle Ages being distinguished by remarkably fine examples of brickwork and ornamental work in terra-cotta. Towards the close of the seventeenth century, an Italian, named M. Fabbroni, rediscovered an ancient invention, which had been completely

lost for many generations, namely, the manufacture of bricks sufficiently light to float in water. Strabo speaks of these bricks as having been made with an earth found at Pisane, in the Troad, and Poseidonius mentions others of a like character as having been made in Spain "of an argillaceous earth, wherewith vessels of silver are cleansed" (probably rottenstone). M. Fabbroni succeeded in producing these floating bricks from "fossil meal," an infusible earth found in abundance over a considerable area of certain districts in Italy. They were only one-sixth the weight of an ordinary clay brick, and on this account were highly esteemed for vaulting church roofs and similar architectural work. The earth of which they were composed consisted, according to Ehrenberg, the German microscopist, almost entirely of the siliceous skeletons of minute water-plants. The bricks with which the arching of the floor in the Berlin Museum is built were made from this material, in combination with a certain proportion of clay "slip."

Among many of the Asiatic nations, bricks of excellent quality have been made from a very remote period, and are to be found in buildings erected centuries ago. A very full account of the history of brick-making in India will be found in the "Professional Papers on Indian Engineering" of Major Falconnet, R. E., published in May, 1874.

In China, bricks are faced with porcelain, and in Nepaul they are richly ornamented by the encaustic process and in relief.

Brick-making was found by the conquerors of Peru to be a flourishing industry in the ancient empire of the Incas, and we have the testimony of Spanish historians, as well as that of Humboldt, Prescott, Stephens and Squier, that both in Peru and in the more northerly regions of Yucatan, and Mexico, there are still extant fine structures in brick, as well as in porphyry and granite, the work of races which have long since passed away.

The scarcity of stone in Holland and the Netherlands naturally led the inhabitants, at a very early period, to seek some other durable material for building purposes, and brick has been almost exclusively employed in the construction not only of private dwellings and commercial establishments, but of ecclesiastical structures and other public edifices. Very fine examples of brickwork in two colors abound, the most notable, perhaps, being at Leeuwardein, in Friesland. The material used in Dutch bricks is chiefly the slime deposited in the numerous rivers and arms of the sea. This is collected by men in boats, who use long poles, furnished at the end with a cutting circle of iron, and a bag-net with which the slime is brought to the surface. Bricks of exceptional hardness are made with a mixture of this slime and sand from the banks of the river Maas. Ordinary house bricks and tiles are chiefly made at Utrecht, from brick-earth found in the vicinity. For the production of the special make of bricks known as "Flemish bricks," which are manufactured in France, Flanders, and the corresponding Belgian frontier, sand from the Scheldt is principally used. At Ghent, as well as at other points lower down the river, the supply of this material constitutes an important branch of the trade of the district. In preparing brick-earth, the slime and sand are well mixed, and then kneaded together with the feet, special care being taken with this operation, so that a perfectly homogeneous mass may be the result. The mixture is then deposited in heaps, and is moulded and dried in the same way as in this country. The kilns used for burning vary in size, some being large enough to contain as many as 1,200,000 bricks. Peat is the fuel ordinarily used for firing.

England seems to owe the introduction of the art of brickmaking to the Romans. Some specimens of their work which have been discovered date back as far as A.D. 44. The bricks in these early examples are nearly all of the wall-tile form, the use of which, as a bond in rubble construction, has been already adverted to. These large thin bricks continued in use, under the same conditions, until about the time of the Norman Conquest, when regular masonry gradually superseded rubble-work. A casual reference in the Saxon chronicles shows that bricks were made under the direction of Alfred the Great, but these were probably the bonding bricks just mentioned. The earliest instance of the use of bricks

of the modern or Flemish type is said to be afforded in the work at Little Wenham Hall, Norfolk (A.D. 1260). These bricks are of a deeper red than those generally used in Suffolk and the adjacent counties, but paler in tint than the common red brick. The use of brick in England as an ordinary building material, even for important structures, does not seem to have become at all general until the reign of Henry VIII, although there are some few brick buildings of the two previous reigns. Herstmonceaux Castle, Sussex, and the Gate of the Rye House, in Hertfordshire, were built in the early part of the reign of Henry VI, and the following are among the best examples of erections in brick from this date to the close of the reign of Henry VIII:—Tattershall Castle, Lincolnshire, A. D. 1440; Lollards' Tower, Lambeth Palace, A.D. 1454; Oxborough Hall, Norfolk, A.D. 1482 (about); Gateway of Hadleigh Rectory, Suffolk, close of fifteenth century; the older portions of Hampton Court Palace, A.D. 1514; and Hengrave Hall, Suffolk, A.D. 1538 (completed). Thorpland Hall and the Manor House at East Barsham, both in Norfolk, were built during the reign of Henry VII, and the Parsonage at Great Snoring, in the same county, during that of his successor. The remains of these buildings exhibit some of the finest specimens of ornamental brickwork to be found in this country. Throughout the reign of Elizabeth, the employment of brick would seem to have been reserved for the construction of mansions and other extensive works. In common buildings, the method ordinarily adopted was that of filling in a framework of timber with lath and plaster; and, even when the use of bricks became general, they were only introduced in panels between a framework of timber. In the first year of the reign of Charles I (1625) the size of bricks was regulated by a special order, and from about this period their use seems gradually to have become more general in shops and private houses, for, on the rebuilding of that portion of London which was destroyed by the Great Fire in 1666, the new erections were all of brickwork. So rapidly did the use of the material spread that the 19th Car. II, cap. 11, fixes "the number of the bricks in the thickness of the walls" of the several rates of dwelling-houses of the period. The records of the Corporation of the City of London also furnish evidence of the favor with which brick had come to be regarded as a constructive material, for about this time a resolution was passed in the following terms: "That they (the City surveyors) do encourage and give directions to all builders, for ornament sake, that the ornaments and projections of the front buildings, be of rubbed bricks; and that all the naked parts of the walls may be done of rough bricks, neatly wrought, or all rubbed, at the discretion of the builder." A special feature of brickwork at the close of the seventeenth and commencement of the eighteenth century was the enrichment of house-fronts by the introduction of ornaments carved with a chisel. Mr. Dobson's treatise on "Brick and Tile Making," published in Weale's Rudimentary Series, contains a sketch of a house in St. Martin's Lane, built by a person named May, about 1739, which is a fine example of this species of work in red brick. Two fluted Doric pilasters support an entablature, the mouldings, flutings, and ornaments of the metopes, having been carved with a chisel after the erection of the walls.

In the year 1784 a duty of half-a-crown per thousand was imposed on bricks of all kinds (24 Geo. III, cap 24), the tax being raised ten years after to 4s. per thousand (34 Geo. III, cap. 15). In 1803 a classified schedule of duties on bricks and tiles of different qualities and sizes was substituted for the uniform duty hitherto imposed. Thirty years after (by the 3d Wm. IV, cap. 11), the duty on bricks was again raised, the common sorts being subjected to an impost of 5s. 10d. per thousand, while tiles were wholly relieved from taxation. These duties were the subject of a Commission of Inquiry in 1836, and in 1839 the 2d and 3d Vic, cap. 24, relieved the trade of the vexatious restrictions imposed by the schedule of duties hitherto in force, and re-established a uniform duty of 5s. 10d. per thousand on all bricks "of which the cubical contents do not exceed 150 cubic inches," without regard to their form or quality. In 1850, bricks ceased to be the subject of taxation, the duty being wholly repealed (13 Vic, cap. 9). The development of the

brickmaking industry during the first half of the nineteenth century may be estimated from the following statement, in round numbers, of the total make of bricks upon which duty was paid at the close of each decade from 1820 until the repeal of the tax :—1820, 914 millions; 1830, 1,100 millions; 1840, 1,400 millions; 1850, 1,700 millions. Four years later, it was estimated that the total number was considerably in excess of 2,000 millions, the capital employed in this branch of industrial enterprise at that period exceeding £2,000,000.

The employment of machinery in the manufacture of bricks appears to have had its origin either in this country or in the United States. Some of the earliest American patents were taken out in 1792, 1793, 1800, 1802, 1806, and 1807. The records containing the specifications of these inventions were unfortunately burnt in 1836. Prior to June of that year, 122 patents for brick and tile machines had been granted in the United States, and upwards of 500 have since been taken out. In England, as early as the year 1619, we find, among the Specifications of Letters Patent, that the eleventh granted was for the protection of the "Arte of making a certain engine to make and cast clay, &c." This first idea of a machine for making bricks consisted of a large pan or table, containing moulds, which were filled with brick earth and a heavy roller passed over them to force the earth into the moulds. The surplus clay was then scraped off the top, and the bricks were ready for ejection from the moulds. This was, no doubt, a somewhat crude arrangement, but it approaches closely, in principle, the most approved machines of the present day. We do not, however, meet with any record of the introduction of brick-making machines, the operations of which were regarded as a practical success prior to the year 1839, when Messrs. Cooke & Cuningham patented one, which was capable of turning out 18,000 bricks in ten hours. In November, 1859, Mr. J. E. Clift, of Birmingham, at a meeting of the Institution of Mechanical Engineers, read a paper describing Oates's brick-making machines, which were then in use at Oldbury. The crushing strength of the bricks made by these machines was said to be 8,024 lbs. per square inch as compared with 4,203 lbs. in bricks made by hand from the same material. The cost of Oates's machine was from £150 to £200, exclusive of the engine for driving it, and its turn-out averaged 12,000 bricks per day, or about twenty per minute. In 1861, Messrs. Dixon and Corbett had a machine in work in the neighborhood of Newcastle-on-Tyne which was driven by steam power, and turned out 1,500 bricks per hour. The years 1861 and 1862 were marked by special activity in the production of these machines, the patents granted during this period embracing the following:—Wimball's, Morrell & Charnley's, Green & Wright's, Basford's, Effertz's, Grimshaw's, Morris & Radford's, Poole's, Newton's, Sharp & Balmer's, Platt & Richardson's, Foster's, and Smith's. Up to the year 1868, forty-seven patents relating to bricks and their manufacture had been granted. During the last twenty years many new machines have been invented, and important improvements introduced, and probably over 200 patents for machines connected with the manufacture of bricks and tiles are at present on record.

Mosandria—Another New Metal.—According to the *Correspondance Scientifique* of July 30th, Dr. J. Lawrence Smith, Professor of Chemistry in the University of Louisville, Kentucky, has discovered a new metal belonging to the cerium group, and has named it mosandrium, after Mosander, whose researches on this class of metals are well known. The new earth, mosandria, from which the metal was obtained, differs from the rest of the group of which yttria is the head by its reaction with potassic sulphate, although what this reaction is we are not informed. From cerium oxide, mosandria differs by its solubility in very weak nitric acid and in alkaline solutions supersaturated with chlorine; from lanthanium by the color of its oxide and salts; and from didymium by certain dark rays in the bright part of the spectrum. We shall refer at greater length to this discovery in our next number, giving, if possible, the physical and chemical properties of the new element. —*Chemical News.*

A METHOD OF DEDUCING FORMULAE FROM EXPERIMENTS ON WROUGHT IRON PILLARS.

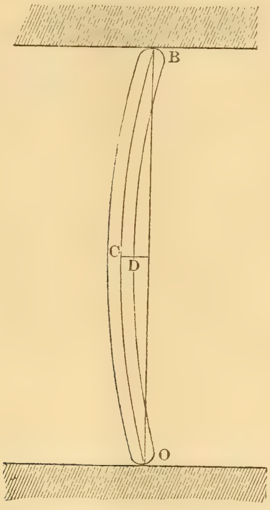
By JOHN D. CREHORE.

Contributed to VAN NOSTRAND'S MAGAZINE.

SINCE the ordinary equation for the deflection of a beam is the equation of a parabola, with reference to the length l, and the deflection D, as the coordinates, let us assume that the equation to the curve of a given pillar sustaining a given load, is the equation of a parabola. Although this assumption may not entirely accord with fact, practically it cannot be very far from the truth, as will appear in the sequel.

Let Fig. 1 represent a pillar sustaining the weight or vertical pressure, P, with the deflection, D, length, l, and least diameter, h.

Fig. 1.



Then the equation to the curve of the neutral line BCO, is

$$y^2 = 2px.$$

if the origin is at C, and the axis of x horizontal, and that of y, vertical. But if O be taken as the origin and the axis of y horizontal, and that of x vertical, then the equation to the curve becomes, after eliminating p,

$$(x-\tfrac{1}{2}l)^2 = \tfrac{1}{4}\frac{l^2}{D}(D-y).$$

$$\therefore\ x^2 - lx = -\frac{l^2}{4D}y. \qquad (1)$$

Differentiating,

$$2xdx - ldx = -\frac{l^2}{4D}dy.$$

$$\therefore\ \frac{dy}{dx} = -\frac{4(2x-l)D}{l^2}$$

$$\frac{d^2y}{dx^2} = -\frac{8D}{l^2} \qquad (2)$$

But we have the radius of curvature

$$\rho = -\frac{\left(1+\frac{dy^2}{dx^2}\right)^{\frac{3}{2}}}{\frac{d^2y}{dx^2}} \qquad (3)$$

$$= \frac{[l^4+16D^2(2x-l^2)]^{\frac{3}{2}}}{8Dl^4}.$$

And, if $x = \frac{1}{2}l$,

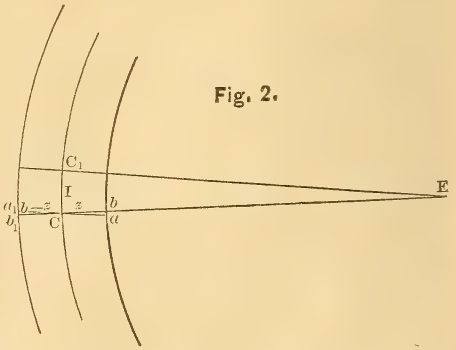
$$\rho = \frac{l^2}{8D},$$

for the value of the radius of curvature at the center of the pillar.

This also follows from (2) and (3), since at the center,

$$\frac{dy}{dx} = o.$$

Suppose that C, Fig. 2, is the center of the neutral surface of the pillar, and that CC_1 is equal to a unit of the length of that surface, and that ρ, the radius of curvature at the center, is represented by



CE. Let ab equal the decrement of a unit of length on the compressed side of the pillar, and a_1b_1, the increment due to

the same unit on the extended side of the pillar. Take z equal to the distance of the neutral surface from the surface of the compressed side, and h equal to the least diameter of the pillar at the center. Then, according to the received theory, we have

$$\frac{1}{\rho}=\frac{ab}{z}=\frac{a_1b_1}{h-z}.$$

Whence

$$\frac{ab+a_1b_1}{ab}=\frac{h}{z}.$$

$$\frac{ab}{z}=\frac{ab+a_1b_1}{h}=\frac{1}{\rho}.$$

But $ab+a_1b_1$ is the total difference of length in the two sides of the pillar for a unit of its length. Therefore

$$\frac{ab+a_1b_1}{1}=\frac{h}{\rho}=\frac{2B_1}{E}=\frac{8Dh}{l^2}$$

and

$$D=\frac{B_1l^2}{4Eh} \qquad (4)$$

where B_1 is the unknown bending unit-strain on the fibres at the surfaces ab, a_1b_1 of the pillar, and E is the modulus of transverse elasticity.

Another expression for the central deflection may be derived from the equality between the total moments of the external and the internal forces in action.

The well known expression for the moment of the internal forces, is

$$M_x=-EI\frac{d^2y}{dx^2} \qquad (5)$$

where I denotes the moment of inertia (so-called) of the cross-section of the pillar, which is here supposed to be uniform throughout.

And the total moment due to the external force P acting vertically, and a force at each end producing a couple with the moment M_1, tending to diminish the deflection of the pillar, is

$$M_x=Py-M_1. \qquad (6)$$

$$\therefore\ -EI\frac{d^2y}{dx^2}=Py-M_1.$$

Hence from (1)

$$EI\frac{d^2y}{dx^2}=\frac{4PD}{l^2}(x^2-lx)+M_1. \qquad (7)$$

Integrating (7), first with the condition that $\frac{dy}{dx}=o$, when $x=\frac{1}{2}l$, and again with the condition that $y=o$ when $x=o$, we find after putting D for y and $\frac{1}{2}l$ for x,

$$EID=\tfrac{5}{48}PDl^2-\tfrac{1}{8}M_1l^2. \qquad (8)$$

If now we suppose the end moment M_1 to vanish, we have at once

$$P=9.6\frac{EI}{l^2},$$

and

$$\frac{P}{S}=Q=9.6\frac{Er^2}{l^2}; \qquad (A)$$

where S=the area, and r=the radius of gyration, of the cross-section of the pillar; and Q is the vertical pressure upon each unit of the cross-section of a pillar having rounded ends that can produce no end couples.

And here it may be noted that Weisbach, and Rankine, and Price, by a different method, find

$$P=\pi^2\frac{EI}{l^2}=9.8696044\frac{EI}{l^2},$$

the first remarking that the formula gives "generally a greater tenacity than the formula for the crushing strength"; the second, that this is the "smallest value of P which is compatible with any bending of the spring"; and the third, that "hereby also we are enabled to calculate the greatest weight that a vertical pillar of a given form and height can bear without being bent by the weight."

Examples of the application of formula (A), are given below.

Resuming equation (8), we have, if the equal end-moments do not vanish,

$$M_1=\tfrac{5}{6}PD-\frac{8EID}{l^2} \qquad (9)$$

Also from (6), the moment at the center is

$$M_c=PD-M_1 \quad \text{for external forces.}$$

$$=\frac{2B_1I}{h}, \quad \text{for internal forces.}$$

$$\therefore\ \tfrac{1}{6}PD+\frac{8EID}{l^2}=\frac{2B_1I}{h}$$

and, after dividing by S,

$$D=\frac{12B_1r^2l^2}{(Ql^2+48Er^2)\,h} \qquad (10)$$

which is the second expression sought for the deflection.

Equating (4) and (10) there results, $Ql^2=o$, which is absurd.

The source of this absurdity may be found in equation (4); for since that value of D was derived from curvature alone, it is the value which D would have from the unit-strain B_1, if B_1 were produced only by couples applied at the ends of the pillar, without direct longitudinal pressure. It is plain, therefore, that the unit-strain B_1 corresponds to a smaller deflection when it is produced by direct end-pressure, than when it is produced by end-couples. The value, $\frac{B_1l^2}{4Eh}$, given by (4), is, therefore, too great, since we assume the unknown value of B_1 to be the same as the value of B_1 in (10).

Let us, therefore, correct equation (4) and write

$$D=\frac{B_1l^2}{(4+\varepsilon)Eh} \qquad (11)$$

so that from (10) and (11) we find

$$\varepsilon=\frac{Ql^2}{12Er^2} \qquad (12)$$

Now if, by resorting to experiments, we can find some function of ε which shall be constant within given limits of $(l\div r)$ or $(l\div h)$, we shall have within those limits, a formula for the value of Q in terms of l, r, E, and ε.

The values of ε in the following tables have been computed from the experiments upon wrought iron pillars, given in Stoney's "Theory of Strains," and in Lovett's "Report on the Progress of Work, etc., of the Cincinnati Southern Railway."

The tests, tabulated in Mr. Stoney's Work, were made under the supervision of Mr. Hodgkinson, and those recorded by Mr. Lovett were made at Pittsburgh and Chicago under competent engineers.

Neither of these sets of experiments is so nearly complete as would be desira-

I.—Solid Rectangular Pillars—Flat Ends.

See Stoney's Theory of Strains, page 263. Modulus of Elasticity, E=24,000,000. $r^2=\frac{1}{12}h^2$.
r=radius of gyration, h=least diameter, l=length of pillar, b=breadth.

$$Q=\frac{P}{S}=\text{resistance, in lbs. per square inch.}$$

Gordon's Formula, as applied by Stoney to this case, is,

$$Q=\frac{35840}{1+\frac{l^2}{3000\,h^2}}.$$

No.	b ins.	l ins.	$\frac{l}{h}$	$\varepsilon=\frac{Ql^2}{12Er^2}$	Q by experiment.	Excess over Q, by Formulae B, C, D, E.	Formulae B, C, F.	Gordon Formula.
1	2.980	120	238.569	1.9351	816	0	0	+ 978
2	2.983	90	179.176	3.2238	2,410	0	0	+ 653
3	3.010	120	156.658	3.4553	3,379	− 172	− 190	+ 525
4	2.995	120	120.603	2.5939	4,280	+1131	+1151	+1848
5	2.980	60	118.343	3.2702	5,604	+ 15	+ 13	+ 719
6	2.980	60	118.343	3.2988	5,653	− 34	− 157	+ 670
7	3.005	90	90.452	3.1636	9,280	+ 339	+ 375	+ 336
8	5.860	90	90.407	3.3756	9,912	− 283	− 257	− 289
9	1.024	90	87.891	3.1392	9,753	+ 435	+ 346	+ 273
10	3.000	120	79.470	2.6743	10,165	+2296	+2054	+1377
11	3.010	60	78.227	3.3068	12,969	− 108	− 115	−1179
12	3.010	60	60.301	2.7374	18,067	− 701	− 648	−1865
13	5.480	60	60.241	2.6760	17,698	− 319	− 279	−1479
14	2.986	30	59.689	2.5019	16,853	+ 651	+ 566	− 470
15	3.000	90	58.824	2.8816	19,987	−2285	−2421	−3343
16	1.024	60	58.594	2.4702	17,268	+ 491	+ 358	− 555
17	3.010	30	39.319	1.6793	27,767	−3545	−6161	−4115
18	3.000	30	30.121	1.1210	29,655	+ 145	−5021	−2137
19	1.023	30	29.326	.9075	25,327	0	− 400	+2527
20	1.023	15	14.663	.3095	34,554	+ 559	− 758	−1105
21	1.023	7.5	7.331	.1090	48,682	0	+1257	−13473

ble, but they are offered as the best at hand. Mr. Lovett says, "In order to test thoroughly the mathematical correctness of the formula [Gordon's] experiments should have been made with the same pressure on columns of different lengths and shapes of cross-section, made of the same iron, of uniform quality, and all fittings made, and measurements taken with great precision. All these conditions could not be realized."

In all the Hodgkinson tests here considered, E, the modulus of transverse elasticity is taken at 24,000,000; which is about the mean value of E found for such iron by that experimenter. For the Chicago and Pittsburgh tests, the values of E are given, and the mean value 27,311,111 has been used except in the case of "rounded or hinged ends."

From the tabulated values of ε we may derive formulae as follows:

1. Take the arithmetical mean of all the values of ε corresponding to $(l \div h) > 60$ and $(l \div h) < 180$, except the anomalous values in Nos. 4 and 10. This mean is $3.27916 = \varepsilon$.

We have, therefore, ε itself approximately constant between these limits of $(l \div h)$.

$$\therefore \ \varepsilon = \frac{Ql^2}{12Er^2} = \frac{Ql^2}{Eh^2} = 3.27916,$$

$$Q = 3.27916E\left(\frac{h}{l}\right)^2 = 78699836\left(\frac{h}{l}\right)^2 \qquad \text{(B)}$$

when $(l \div h) \begin{cases} > 60 \\ < 180. \end{cases}$

2. For values of $(l \div h)$ not greater than 60, we observe that the product

$$\frac{h}{l} \times \varepsilon \times Q,$$

is a function of ε approximately constant.

Using Nos. 12, 13, 14, and 16, and taking means, we have

$$l \div h = 59.65,$$
$$\varepsilon = 2.5964,$$
$$Q = 17,427.$$

$$\therefore \ \frac{Q}{17427} \times \frac{h}{l} \times 59.65 \times \frac{Ql^2}{Eh^2} = 2.5964,$$

$$Q = 134927\sqrt{\frac{h}{l}} \qquad \text{(F)}$$

when $(l \div h)$ is not greater than 60.

3. For the extreme value of $(l \div h) = 238.569$, we may proceed as follows; but the formula may not be reliable for other cases, there being no intervening series to give a law.

	No. 1.	No. 2.	Dif. of logs.
log. $(l \div h)$,	2.3776132	2.2532793	0.1243339
" ε	0.2867054	0.5083644	0.2216590

$$\text{Ratio of dif. of logs.} = \frac{.2216590}{.1243339} = 1.78277.$$

$$\therefore \ \varepsilon\left(\frac{l}{h}\right)^{1.78277} = 33531, \text{ a constant}$$

for these two experiments.

$$\therefore \ Q = 33531E\left(\frac{h}{l}\right)^{3.78277}. \qquad \text{(D)}$$

$(l \div h) \begin{cases} > 180 \\ < 240. \end{cases}$

4. Similarly may we find a formula for values of $(l \div h) < 30$.

	No. 19.	No. 21.	Dif. of logs.
log. $(l \div h)$,	1.4672457	0.8651857	0.6020600
" ε	9.9578640	9.0375286	0.9203354

$$\text{Ratio of dif. of logs.} = \frac{.9203354}{.6020600} = 1.52864.$$

$$\therefore \ \varepsilon\left(\frac{h}{l}\right)^{1.52864} = .00518762, \text{ a constant}$$

for these limits.

Wherefore,

$$\frac{Ql^2}{Eh^2} \times \left(\frac{h}{l}\right)^{1.52864} = .00518762,$$

$$Q = 124503\left(\frac{h}{l}\right)^{.47136}. \qquad \text{(C)}$$

$(l \div h) < 30$.

5. Also for values of $(l \div h)$ ranging from 30 to 60, we may take

$l \div h$	59.65	30	Dif. of logs.
log. $(l \div h)$,	1.7756104	1.4771213	0.2984891
" ε	0.4143716	0.0496056	0.3647660

$$\text{Ratio of dif. of logs.} = \frac{.3647660}{.2984891} = 1.22204.$$

$$\therefore \ \varepsilon \times \left(\frac{h}{l}\right)^{1.22204} = .017559, \text{ a constant.}$$

$$Q = 421419\left(\frac{h}{l}\right)^{.77796}. \qquad \text{(E)}$$

$(l \div h)$, from 30 to 60.

(*See Table II on following page.*)

In the preceding table, under $\frac{h}{t}$, are given the ratios of thickness of metal to least diameter, or of thickness to the mean of the two diameters when h and b are different.

II.—Rectangular Tubular Pillars—Flat Ends.

See Stoney's Theory of Strains, page 271.

Notation as in preceding case. t=thickness of metal.

Gordon's Formula for this case,

$$\frac{\mathrm{P}}{\mathrm{S}}=\mathrm{Q}=\frac{30720}{1+\dfrac{l^2}{3000\,h^2}}.$$

No.	b ins.	h ins.	$\frac{h}{t}$	$\frac{l}{h}$	$\frac{l}{r}$	$\varepsilon=\frac{\mathrm{Q}l^2}{12\mathrm{E}r^2}$	Q by experiment.	Excess over Q, by Formulae G, H.	Excess over Q, by Gordon Formula.
1	4.1	4.1	136.6	29.26	71.672	.19596	10,980	+4138	+2310
2	4.1	4.1	68	29.26	71.672	.34373	19,260	— 781	—1503
3	4.25	4.25	51	28.23	69.149	.41807	25,171	0	— 32
4	4.25	4.25	31.7	28.23	69.149	.35837	21,585	+ 288	— 619
5	8.1	4.1	70	29.26	66.452	.35525	23,169	+1756	+2809
6	8.17	4.1	100.6	29.26	66.394	.23268	15,201	— 733	— 248
7	8.4	4.25	32.3	28.23	64.104	.42778	29,981	+1798	+2881
8	8.5	4.75	25.1	25.30	57.906	.31334	26,913	+ 330	+1940
9	8.5	4.75	19	25 30	56.601	.27810	25,000	—2286	—1297
10	4.25	4.25	31.7	21.10	51.684	.21421	23,201	+2522	+5226
11	8.17	4.1	100.6	22.40	50.902	.14588	16,215	— 636	+2079
12	8.1	4.1	69	22.30	50.669	.21538	24,111	+ 323	+3038
13	8.1	8.1	63.6	14.94	36.595	.09176	19,732	+3505	+4994
14	8.1	8.1	135	14.80	36.252	.06058	13,276	— 643	+1709
15	4.1	4.1	136.6	14.60	35.762	.05137	11,513	—1060	+ 35
16	8.1	8.1	63.6	14.57	35.689	.10216	23,100	—2721	—2612
17	8.37	8.37	60	14.33	35.101	.08712	20,364	+2637	+4993
18	8.37	8.37	38.2	14.33	35.101	.11001	25,716	—4529	—3104
19	8.40	8.40	35.7	14.33	35.101	.11413	26,675	—3100	—1826
20	4.25	4.25	50	14.10	34.538	.09793	23,584	+1287	+3550
21	8.1	8.1	135	11.30	27.679	.03539	13,301	— 862	+ 318
22	8.1	4.1	68.3	10.70	24.366	.45123	21,889	—2863	—1595
23	8.1	8.1	63.6	7.40	18.126	.02647	23,208	—6316	—5618
24	4.1	4.1	136.6	7.30	17.881	.01383	12,402	—2334	—2190
25	4 25	4.25	50	7.00	17.146	.02846	27,417	—4680	—4391
26	8.17	4.1	100.6	6.80	15.493	.01327	15,921	+1798	+2678
27	18	18	36	5.33	13.056	.01803	30,464	—1788	— 898
28	8.1	4.1	68.3	4.70	10.798	.01053	26,010	+2331	+ 69
29	8.1	8.1	63.6	3.40	8.328	.00582	24,153	—1619	—1358

$$r^2=\frac{h^2(h+3b)}{12(h+b)}=\frac{h^2}{6},\ \text{when } h=b.$$

In finding a formula for this set of experiments, we consider only those cases where the metal was so thick that $(h\div t)$ is not greater than 55.

Using Nos. 3, 4, and 27, and taking means, we write

	Nos. 3-4.	No. 27.	Dif. of logs.
log. $(l\div r)$,	1.8397859	1.1158101	0.7239758
" ε	9.5890779	8.2559957	1.3330822

$$\text{Ratio of dif. of logs}=\frac{1.3330822}{0.7239758}$$
$$=1.841335.$$

$$\therefore\ \frac{\varepsilon}{(l\div r)^{1.841335}}=.0001590065 \text{ a constant.}$$

Whence

$$\mathrm{Q}=45794\left(\frac{r}{l}\right)^{.158665}. \qquad \text{(G)}$$

when $(l\div h)<30$, and $(h\div t)<55$.

But when $(h\div t)$ exceeds 55, we find

$$\mathrm{Q}=\frac{55t}{h}\times 45794\left(\frac{r}{l}\right)^{.158665}. \qquad \text{(H)}$$

approximately. And this factor has also been applied to the Gordon formula for these cases.

III.—Hollow Cylindrical Pillars—Flat Ends.

See Stoney's Theory of Strains, page 275. h=diameter of pillar. $r^2=\frac{1}{8}h^2$.

No.	h ins.	$\frac{l}{h}$	$\frac{l}{r}$	$\frac{h}{t}$	$\varepsilon=\frac{Ql^2}{12Er^2}$	Q by experiment.	Excess over Q, by Formulae I, J, K.	Formula L.	Gordon Formula.
1	1.495	80	226.274	15	2.6441	14,673	0		—1601
2	1.964	60	172.816	18.8	2.4064	23,206	0	+ 894	—4588
3	2.340	51.28	145.042	10.8	1.6202	22,179	+2443	+2612	— 351
4	2.350	51	144.250	9.7	1.5733	21,572	+3098	+3246	+ 367
5	2.490	47.8	135.199	23.27	1.9357	29,798	—4582	—4666	—6547
6	1.495	40	113.137	15	1.4047	31,180	—4397	—4960	—4466
7	3.000	40	112.877	20	1.2298	27,671	— 867	—1451	— 954
8	1.964	30.5	86.267	18.8	.8693	33,299	—3935	—5420	—2034
9	3.035	29.6	83.721	18	.7430	29,789	— 128	—1709	+1913
10	4.050	29.6	83.721	29	.6745	27,657	+2004	+ 423	+4045
11	4.060	29.6	83.721	26.1	.6373	26,263	+3398	+1817	+5439
12	2.335	25.7	72.690	11.4	.5502	29,998	+1108	— 826	+3571
13	2.350	25.5	72.125	10.6	.5311	29,330	+1858	— 50	+4333
14	2.490	24.1	68.165	23.27	.5700	35,100	—3317	—5956	— 784
15	4.052	22.2	62.791	30.9	.4568	33,331	— 654	—2830	+1850
16	4.000	22.2	62.791	16.5	.3582	26,046	+6631	+4455	+9135
17	4.000	22.2	62.791	16	.3645	26,503	+6174	+3998	+8678
18	4.000	22.2	62.791	16.5	.3825	27,816	+4861	+2685	+7365
19	2.490	21	59.397	23.27	.1482	36,489	—3203	—5465	— 778
20	1.495	20	56.569	15	.3854	34,220	— 375	—2728	+1922
21	6.180	19.4	54.871	65	.3495	33,375	+ 819	—1570	+3019
22	6.360	18.9	53.334	49	.3558	35,985	—1462	—3766	+ 642
23	1.964	15.3	43.275	18.8	.2413	36,980	+ 59	—2609	+1015
24	3.995	15	42.426	16.3	.1881	30,024	+7263	+4577	+8078
25	3.995	15	42.426	16.5	.2159	34,453	+2824	+ 148	+3649
26	6.366	14.1	39.881	48.9	.2313	41,664	—3593	—6336	—3249
27	2.343	12.8	36.204	11.1	.1752	38,214	+1117	—1256	+ 625
28	2.335	12.8	36.204	11.4	.1680	36,639	+2638	+ 319	+2146
29	2.335	12.8	36.204	11.4	.1623	35,389	+3942	+1569	+3450
30	2.383	12.5	35.355	9.7	.1468	33,107	+6522	+3686	+5825
31	2.343	12.3	34.790	11.6	.1684	39,569	+ 292	—2565	— 576
32	2.373	12.2	34.507	10.27	.1531	36,906	+3066	+ 187	+2125
33	6.175	9.7	28.075	61.1	.1006	38,355	+4491	— 173	+1360
34	3.000	9.3	26.305	19.6	.0905	37,392	+6403	+3105	+2420
35	4.000	7	19.799	16	.0651	47,844	+ 347	—4167	—7183
36	4.026	6.95	19.657	16	.0653	48,576	— 268	—4832	—8265
37	6.125	4.9	13.859	62.5	.0276	41,361	+12779	+3555	— 681

The Gordon Formula here is, $Q=\dfrac{40960}{1+\frac{l^2}{3000h^2}}$.

1. Using the mean values of ε and of $(l\div r)$ in Nos. 35, 36, and Nos. 8, 9, 10, 11, we write,

$(l\div r)$	84.358	19.728	
ε	0.7310	0.0652	Dif. of logs.
log. $(l\div r)$	1.9261263	1.2950831	0 6310432
" ε	9.8639174	8.8142476	1.0496698

$$\text{Ratio of dif. of logs.}=\frac{1.0496698}{0.6310432}=1.6634.$$

$$\therefore\ \varepsilon\times\left(\frac{r}{l}\right)^{1.6634}=.00045711, \text{ a constant.}$$

$$Q=131648\left(\frac{r}{l}\right)^{.3366}. \qquad \text{(I)}$$

when $(l\div h)<30$.

2. Similarly, from Nos. 2 and 8, 9, 10, 11, we find, when

$$(l\div h)\begin{cases}>30\\<60,\end{cases}$$

$$Q=132807\left(\frac{r}{l}\right)^{.3386} \qquad \text{(J)}$$

3. And from 1 and 2 we derive in the same manner,

$$Q=11438000\left(\frac{r}{l}\right)^{1.65043}. \qquad \text{(K)}$$

$(l\div h)$ from 60 to 80.

4. We may in all these cases, of course, find values of ε by interpolation, and thence derive Q from the equation

$$\varepsilon=\frac{Ql^2}{12Er^2},$$

or Q may be derived directly by interpolation.

For the case of hollow cylinders, $(l\div h)$ being not greater than 60, we get an approximate formula involving only second differences, by the following arrangement:

$l\div h$	ε	D_1	D_2
10	.11		
		.24	
20	.35		.11
		.35	
30	.70		.11
		.46	
40	1.16		.11
		.57	
50	1.73		.11
		.68	
60	2.41		

From which, by the "method of differences,"

$$\varepsilon=.11+.24(n-1)+.11\frac{(n-1)(n-2)}{2},$$

$$n=\frac{l}{10h},$$

$$\therefore\ Q=12E\varepsilon\left(\frac{r}{l}\right)^2=36,000,000\varepsilon\left(\frac{h}{l}\right)^2. \quad \text{(L)}$$

Mean value of E=27,311,111.

Gordon formula here is

$$Q=\frac{50800}{1+\frac{l^2}{3000h^2}}$$

using the mean of the experimental values of the numerator.

To find formula M we have from

Nos. 29, 28, 10, $l\div r=111.067$, $\varepsilon=1.28803$

No. 6, $l\div r=$ 61.609, $\varepsilon=$ .43430

log. $(l\div r)$, 2.0455851 1.7896453 0.2559398=dif.

" ε 0.1099260 9.6378014 0.4721246=dif.

$$\text{Ratio of dif. of logs.}=\frac{0.4721246}{0.2559398}=1.84467.$$

$$\therefore\ \varepsilon\left(\frac{r}{l}\right)^{1.84467}=.000217018, \text{ a constant.}$$

$$Q=71124\left(\frac{r}{l}\right)^{.15533} \quad \text{(M)}$$

$(l\div h)$ from 20 to 40.

IV.—The "Phoenix Column"—Flat Ends.

See Thomas D. Lovett's Report.

No.	h ins.	$\frac{l}{h}$	$\frac{l}{r}$	r^2	$\varepsilon=\frac{Ql^2}{12Er^2}$	Q by experiment.	Excess over Q, by Formula M.	Excess over Q, by Gordon Formula.
29	8.250	40.7	112.4	8.935	1.4111	36,600	—2444	—3872
28	8.250	40.7	112.4	8.935	1.3417	34,800	— 644	—2072
10	8.125	39.9	108.4	8.935	1.1113	31,000	+3350	+7874
6	8.050	22.4	61.6	8.536	.4343	37,500	0	+6021

V.—The "American Bridge Co.'s Column"—Flat Ends.

See Lovett's Report.

Two flanged bars riveted to the flanges of an I-beam.

No.	h ins.	$\frac{l}{h}$	$\frac{l}{r}$	r^2 ins.	$\varepsilon=\frac{Ql^2}{12Er^2}$	Q by experiment.	Excess over Q, by Formula N.	Excess over Q, by Gordon Formula.
15	8	45	155.1	5.388	1.7394	23,700	0	— 655
19	9.5	34.1	88.1	13.510	.6591	27,800	+1353	+ 18
18	9.5	25.3	81.6	8.653	.6398	31,500	—1609	+ 312

Using the mean value of f for the numerator, the Gordon formula becomes,

$$Q=\frac{38600}{1+\frac{l^2}{3000h^2}}.$$

We find formula (N), by taking mean values of $(l\div r)$ and ε in Nos. 18, 19, and combining with No. 15.

$(l\div r)$	155.1	84.85
ε	1.7394	.64945

$$\frac{\log. 1.7394-\log. .64945}{\log. 155.1\ -\log. 84.85}=1.63346$$

$$\therefore\ \varepsilon\left(\frac{r}{l}\right)^{1.63346}=.00045937,\text{ a constant.}$$

$$=\frac{Ql^2}{12Er^2}\times\left(\frac{r}{l}\right)^{1.63346}=\frac{Q}{12E}\left(\frac{l}{r}\right)^{.36654}$$

$$Q=150552\left(\frac{r}{l}\right)^{.36654} \qquad \text{(N)}$$

$(l\div h)$ from 25 to 45.

VI.—The "Keystone Column"—Flat Ends.

See Lovett's Report.

No.	$\frac{l}{h}$	h ins.	$\frac{l}{r}$	r^2 ins.	$\varepsilon=\frac{Ql^2}{12Er^2}$	Q by experiment.	Excess over Q, by Formulae O, P.	Excess over Q, by Gordon Formula.
27	37.6	8.625	103.5	9.798	.9088	27,800	—2564	—3177
4	35.2	9.2	98.2	10.883	.7093	24,100	+1699	+1720
26	34.6	9.375	96.9	11.178	.7880	27,500	—1556	—1607
25	33.7	9.625	95.8	11.424	.5916	21,100	+4963	+5179
30	34.1	9.5	95.8	11.464	.8411	30,000	—3937	—3899
31	34.1	9.5	95.8	11.464	.7122	25,400	+ 663	+ 701
24	34.1	9.5	93.4	12.041	.6650	25,000	+1353	+1101
9	20.3	8.85	64.3	7.833	.4039	32,000	— 69	— 151
7	21.7	8.3	59.3	9.206	.3222	30,000	+2035	+1312
8	20	9	55.9	10.353	.3524	36,900	—4790	—4936
3	19.5	9.25	54.7	10.834	.2628	28,800	+3339	+3350
2	6.5	9.3	18.054	11.044	.0334	33,600	0	+2122

Gordon Formula, $Q=\frac{36225}{1+\frac{l^2}{3000\,h^2}}$, using the mean value of f.

1. To find formula (O), use mean values of $(l\div r)$ and ε in Nos. 27, 4, 26, 25, 30, 31 and 24, and in Nos. 9, 7, 8, 3.

Then $(l\div r)$	= 97.06	58.55
ε	=.74514	.33532

$$\frac{\log. .74514-\log. .33532}{\log.\ 97.06-\log.\ 58.55}=1.5798.$$

$$\therefore\ \varepsilon\left\{\frac{r}{l}\right\}^{1.5798}=.000540995,\text{ a constant,}$$

$$=\frac{Ql^2}{12Er^2}\times\left(\frac{r}{l}\right)^{1.5798},$$

$$Q=177301\left(\frac{r}{l}\right)^{.4202} \qquad \text{(O)}$$

$(l\div h)$ from 20 to 40.

2. Similarly, from Nos. 9, 7, 8 and 3, and No. 2, we find

$(l\div r)=$	58.55	18.054
ε =	.33532	.0334

$$\frac{\log. .33532-\log.\ .0334}{\log.\ 58.55-\log. 18.054}=1.96.$$

$$\therefore\ \varepsilon\left(\frac{r}{l}\right)^{1.96}=.000115087,\text{ a constant,}$$

$$=\frac{Ql^2}{12Er^2}\times\left(\frac{r}{l}\right)^{1.96},$$

$$Q=37718\left(\frac{r}{l}\right)^{.04} \qquad \text{(P)}$$

$(l\div h)\ <25.$

(*See Table VII on following page.*)

The Gordon formula here becomes,

$$Q=\frac{44400}{1+\frac{l^2}{3000h^2}}.$$

Formula (R) is found as follows:

	No. 22.	No. 23.
$(l\div r)=$	102.050	84.458
ε =	.9533	.7226

VII.—The "Square Column"—Flat Ends.

See Lovett's Report. Two Channels and Two Plates.

No.	h ins.	$\frac{l}{h}$	$\frac{l}{r}$	r^2 ins.	$\varepsilon=\frac{Ql^2}{12Er^2}$	Q by experiment.	Excess over Q, by Formula R.	Excess over Q, by Gordon Formula.
22	7.5	41.6	102.050	9.347	.9533	30,000	0	—1842
32	9.25	30.9	98.096	10.909	.8867	30,200	+ 441	+3480
23	8.43	34.1	84.458	11.628	.7226	33,200	0	—1202

VIII.—Pillars with Rounded or Hinged Ends.

See Lovett's Report.

No.	Kind.	h ins.	l ins.	r^2 ins.	$\frac{E}{100000}$	Q by experiment.	Excess over Q, by Formula A.	Excess over Q, by Gordon Formula.
16	American	8	240	5.479	289	26,700	— 309	—1927
17	"	10	240	8.733	231	26,500	+7122	+2371
13	"	10.75	312	8.733	304	24,000	+2301	—1602
14	"	10	312	8.733	260	22,000	+ 392	+2223
11	Phoenix	8.125	324	8.935	271	21,700	+ 444	—2315
5	Keystone	9.22	324	10.945	295	22,000	+7527	— 61
21	Square	10	309	11.000	310	25,500	+8785	—1087

$$\frac{\log.\ .9533-\log.\ .7226}{\log.\ 102.050-\log.\ 84.458}=1.46437.$$

$$\therefore \varepsilon\left\{\frac{r}{l}\right\}^{1.46437}=\frac{Ql^2}{12Er^2}\times\left\{\frac{r}{l}\right\}^{1.46437}$$

$$=.00109037, \text{ a constant.}$$

$$\text{Whence } Q=357350\left(\frac{r}{l}\right)^{.53563}. \quad (R)$$

$(l\div h)$ from 25 to 30.

Gordon formula here,

$$Q=\frac{39957}{1+\frac{l^2}{1500h^2}}.$$

It will be noticed that formula (A), viz.

$$Q=9.6E\left(\frac{r}{l}\right)^2,$$

gives, in general, the values of Q too large; and hence it is, in these cases, nearer the truth than the formula above cited as given by Weisbach, Rankine, and Price.

Experiments, however, are wanting, from which to derive complete formulae for pillars.

It is evident that the method here applied to wrought iron pillars, is equally applicable to pillars, struts, or columns, of any other material.

Sharpening Files.—Mr. B. C. Tilghman has recently discovered another and very interesting application of the sand-blast to industrial purposes. He has found that by subjecting worn files to the action of the jet, the cutting edges are rapidly renewed, and the file is made sharper than when new. A stream of fine sand, impelled at a high velocity by a jet of steam, is applied to a file at an angle of from ten to fifteen degrees from its face, the file being moved about so that all parts may be acted on. The sand is very fine grit, prepared by washing and settling. It is used in the state of very soft slime, drawn from a receiver.—*Engineering.*

THE VENTILATION OF COAL MINES.

By GEORGE G. ANDRE.

Transactions of the Society of Engineers.

The late coal panic has shown us to what degree our material prosperity is dependent on that mineral. It would seem, indeed, that the exhaustion of our coal fields must inevitably be followed by the utter collapse of those industries which have made this country what it is, and that even a slightly decreased production would seriously affect their position. Coal having assumed a relation of such vital importance to our social existence, its extraction from the earth has become one of the foremost engineering questions of the day, and accordingly increased attention is now being directed to it. The author of the present paper has therefore deemed the time opportune for a discussion of some of the facts relating to what is certainly one of the most important subjects of mine engineering, namely, the ventilation of the workings. One of the effects of the recent panic may be seen in the greater activity shown at existing collieries as well as in the opening out of many new ones. In their haste to extract the valuable mineral there is danger that managers and engineers may not give due attention to those matters which are essential to an efficient ventilation, especially in the laying out of new works. Hence another reason for calling attention to the subject at this time. Moreover it is almost an indisputable fact that 90 per cent. of those disastrous explosions which so frequently occur are wholly due to a defective ventilation. Thus it appears that though the principles of a good ventilation are generally understood and acknowledged in theory, they are still far from being applied in practice. By the expression "defective ventilation," it is not intended to mean merely insufficient ventilation, but also all systems of ventilating a mine that are established upon false principles, quite irrespective of the quantity of air passing through it in a given time. Of course it is quite impossible to treat so large a subject in a paper like the present, and therefore no such attempt will be made. All that the author proposes to do is to direct attention to a few essential points, and instead of adducing anything new, to simplify what is already known.

It is agreed on all hands, and Parliament has recently enacted, that a sufficient quantity of air should be constantly passed through a mine to dilute and render harmless the noxious gases evolved or generated therein. But there does not appear to be any definite understanding among mining men as to what constitutes a sufficient quantity, and the practice among careful men is to pass an excess of air in order to be on the safe side. No doubt this is erring in the right direction; but it is better not to err at all. Besides, such a practice begets a vagueness of notion concerning the requisite quantity of air that conduces neither to correctness of judgment nor to progress in knowledge. It may in some cases be a source of danger even, for a Davy lamp is not safe in a violent current of air that has been suddenly fouled by a blower, while the cost of producing the current is enormously increased. Of course the question is an intricate and a difficult one, depending upon numerous conditions that vary from district to district, and even from mine to mine. A general solution is therefore not to be looked for; but it is both practicable and highly desirable to lay down some definite and invariable basis upon which every individual case may be accurately and readily calculated.

The atmosphere of a coal mine is vitiated by several causes: the breath of men and horses, the combustion of lights, the moisture of the ground, the exhalation of gases from the strata, and the chemical changes which are constantly going on in the substances exposed to the influence of the air. Some of these causes are constant in their action or nearly so, while others are extremely variable. The former we can estimate with accuracy; with the latter we can deal only approximately.

The average quantity of air breathed by man is usually assumed by writers

on mine ventilation to be 800 cubic feet per minute. This quantity is, however, altogether erroneous as a basis on which to calculate an adequate amount of ventilation. It has been stated by eminent medical authorities that the mean of several hundred experiments conducted with great care by means of very accurate instruments was 502 cubic inches per minute, and that this quantity was increased to 1500 cubic inches, or nearly three times as much, by the exertion of walking four miles an hour. We all know from experience that a much larger quantity of air is breathed when undergoing violent exercise than when at rest; and we cannot therefore found a calculation relating to men subjected to great physical exertion in a mine upon what has been ascertained respecting a man lying motionless on his bed. It may be assumed that the average amount of labor undergone by each man and boy in the extraction of coal is at least equal to that of walking four miles an hour; and hence the quantity of air required for each man will be 1500 cubic inches, or say, one cubic foot per minute. The miasmata or effluvia derived from the various secretions of the body are a potent cause of vitiation in the atmosphere. The unpleasant smell of a close bedroom in the morning is due wholly to this cause, and in ascertaining the state of ventilation in a room by what is known as the "nose test," it is these effluvia which furnish the requisite indications. Moreover the air in passing over the human body becomes heated. These causes are greatly increased in intensity by the augmented temperature due to violent exertion, such as is undergone in mines. Added to this there is the dust caused by each workman floating in the atmosphere. We must therefore provide an additional quantity of air to keep the atmosphere pure and cool, and this quantity may be taken as one cubic foot per minute. This allows a covering or film of air over his whole body about $\frac{3}{4}$ inch thick, which film is changed every minute. Each man's lamp will heat the air and foul it with the products of combustion to a degree requiring about one cubic foot per minute. Thus the quantity of air requisite per man will be three cubic feet per minute. A horse fouls about six times as much as a man, and will therefore require twelve cubic feet per minute.

The foregoing may be considered the constant causes of vitiated air, and are easily dealt with. We come now to consider the varying causes, namely, the moisture of the ground and the gases evolved. It is impossible to treat these otherwise than approximately, but an approximation sufficiently near for practical purposes may be arrived at. The gases existing in a coal mine are chiefly carbonic acid or choke-damp and carburetted hydrogen or fire-damp. Other gases are generated, but in such small quantities that their presence is not of much importance, except perhaps when blasting is extensively practiced. These two gases, carbonic acid and carburetted hydrogen, are continually being exhaled in greater or less quantities from the face of the exposed strata, and therefore the total quantity is to a certain degree dependent on the extent of surface exposed. They are given off more abundantly from fissures, especially in the neighborhood of faults. Considerable quantities of carbonic acid are also in every mine due to the respiration of men and horses, the combustion of lights and the deflagration of gunpowder, all of which causes are subjects of calculation. In smaller quantities, carbonic acid is formed by the fermentation and decomposition of vegetable matter.

When the proportion of carbonic acid to the atmospheric air reaches $\frac{1}{10}$th the compound will not support combustion, and is fatal to life. A proportion of $\frac{1}{15}$th of carburetted hydrogen renders the compound inflammable. These proportions may be taken as the limits which must never be reached; or, to further simplify the matter, the proportion of pure atmospheric air must, in a mine, never be less than $\frac{14}{15}$ths of the total volume therein contained.

The question now is what quantity of air in a dry mine, making but little gas of any kind, is sufficient, irrespective of the respiration of men and horses, to ensure this proportion under all conditions. This problem, as we have said, can only be solved approximately, but as it is mainly a matter of experience and calculation, a fairly close approximation may be arrived at. A careful investigation of this matter has led the author to con-

clude that one cubic foot of air per second for every 100 square yards of surface is an adequate quantity. This allows for the exhalation and formation of .067 cubic foot of impurities, that is, noxious gases, watery vapor, and solid floating matter per second. In other words, one cubic foot of air per 100 yards of surface is equivalent to a film about $\frac{3}{4}$ inch thick spread over that surface, which film is changed every minute. And .067 cubic foot of gases to the same extent of surface is equivalent to a film about $\frac{1}{20}$ inch thick formed every minute. Of course the gas is not exhaled in this regular way over the whole surface exposed. But the quantity here given is approximately that which is given off the surface at the worst parts under the conditions previously mentioned.

This quantity of one cubic foot per second for every 100 yards of surface may be taken as a reliable basis upon which to calculate an adequate ventilation. It must be borne in mind that the quantity is only just sufficient under the very favorable conditions which we have assumed, and is, therefore, analogous to the breaking strain of materials. In every case it will have to be multiplied by an appropriate factor of safety, the value of which must be determined by the conditions of the case. All mines are, in a greater or less degree, liable to give off "blowers," that is pent-up accumulations of gas which are liberated by the boring and driving, or by falls of roof. The gas issues from the blowers with a sound resembling, in the smaller ones, the simmering of a teakettle, and in the larger that of blowing off high-pressure steam. Of course it is quite impossible to estimate the value of these blowers with anything like accuracy, just as it is impossible to estimate the value of the strain to which a structure exposed to sudden shocks may be subjected. In both cases a sufficiently large factor of safety must be taken to include possibilities and to leave an ample margin of safety. It may be remarked that no system of ventilation can be calculated for the large blowers previously mentioned. They are fortunately of rare occurrence, and when one does occur, the only practicable plan is to call out the men until it has exhausted itself. When their presence is suspected, safety lamps alone should be used. The small blowers are more constant in their action, and are capable of being estimated with some degree of precision.

Besides varying in gaseous products, mines differ in degree of moisture. Blasting is also more extensively practised in some mines than in others. All of these circumstances will influence the factor of safety, the value of which must be determined for every individual case, and which will vary from 2 to 6. Let us now apply these principles to an example. Suppose we have to ventilate a mine in which the air-courses have a total length of 2000 yards, giving a total surface of, say, 14,000 square yards; and, to simplify the calculation, we will suppose that the number of men and horses are 100 and 10 respectively. Respiration, perspiration, and lamps will then require $100 \times 3 + 10 \times 12 = 420$ cubic feet per minute; and the gases, vapors, &c., will need $\frac{14000}{100} = 140$ cubic feet per second = 8400 cubic feet per minute. Supposing the mine to generate but little fire-damp and to be not particularly wet, we may take the factor of safety at 3, which will give $(840^{\circ} + 420) \times 3 = 26{,}460$ cubic feet per minute as the adequate amount of ventilation. In this case we have taken the surface and the factor of safety for the entire mine; but when, as it usually is, the mine is divided into several districts, which are aired by separate currents, the air must be apportioned according to the surface of each district and the factor of safety determined by the nature of the seam or the conditions of the workings. Thus the factor of safety may vary from district to district.

When the proper quantity of air has been determined, the next question is, how to get it through the workings. One mode of effecting this is to provide contracted air-ways and to give the ventilating current a high velocity. Another is to have spacious air-ways and a low velocity. For economical reasons, the former is but too frequently adopted. In many cases a drift is driven with an insufficient sectional area; in other cases, falls of roof, the creep of the floor, and other causes reduce the dimensions of an air-passage to those of a mere creeping hole. Fully 25 per cent. of the air-

courses in collieries which are now being worked, and in which the ventilation is said to be perfect, can only be entered by a man in a crawling posture. The economy of a system that lays out works in such a manner, or that allows them to get into such a condition, is more than doubtful. The drag of the air, that is, its retardation by contraction and friction, is enormously increased thereby, and the consumption of fuel in the furnace, or in the engine when a mechanical ventilator is used, is augmented in a like proportion. But even when the additional cost of fuel is incurred, the friction with small passages and high velocities is so great that it is impossible to ensure sufficient ventilation at all times, and hence there is the constant risk of accident, with its accompanying danger to life and property. It may therefore be laid down as one of the essential principles of an efficient ventilation, that spacious air-ways are indispensable. A limit that may be adopted with advantage is, that all air-ways other than shafts should allow a sufficient quantity of air to pass with a velocity not exceeding 6 feet per second.

Another important fact connected with the dimensions of air-ways is, that the return passages require a larger sectional area than the intake passages. When the ventilating current enters the return ways from passing through the workings, it is laden with the various gases that are generated in a mine, watery vapor, the solid products of combustion and coal dust, and its temperature, and consequently its bulk, is considerably increased. Thus it has lost a great part of its elasticity and it drags more heavily. To compensate this, its friction should be lessened by increasing the sectional area of the passage. To ensure a proper state of ventilation there should be two return ways, each equal in sectional area to the intake. As far as practicable, the air-courses should have at all parts of their length the same sectional area. It is, perhaps, hardly necessary to remark that they should be kept free from all obstructions, such as projecting pieces of timber or stones.

One of the most effective means of diminishing the friction is to shorten the runs by dividing the workings into districts and ventilating each with a separate air-current. Thus, a shaft 12 feet in diameter will afford sufficient area for five different air-ways each of 20 feet area. This system of splitting the air, as it is called, though well-known, is not adopted so extensively as it ought to be. There are many mines in which the old unwholesome and dangerous practice of passing the air through in one column from the downcast to the upcast shaft still prevails, though the evils attending it have long been acknowledged by the majority of viewers. An additional and great advantage possessed by the system of ventilating by districts is that of confining the effects of an explosion to a small part of the workings. In all cases of splitting the air, the split should be made as near the downcast shaft, and the several branches reunited as near the upcast as possible, and the air-ways between the shafts and the points where the branches separate and reunite should have a large sectional area.

The distribution of the air through the workings requires great skill. There are, indeed, few matters connected with mining that test the skill and ability of the engineer more than this. A very slight variation in the direction of the ventilating current may make all the difference between a good and a defective, and consequently a dangerous ventilation. And yet this important duty is often left to ignorant hands. No doubt the men who are entrusted with this important work are experienced men, and men who on that account would be called practical. But there are things which experience alone cannot teach, at least in the lifetime of a single individual. A certain amount of scientific knowledge and an acquaintance with collateral subjects, such as the composition of gases, the nature of fluids, and the laws which they obey, are absolutely necessary to enable a man to manage efficiently the ventilation of a mine. And such knowledge is part of a liberal education.

The essential conditions of a good distribution are: (1) That the air shall not pass from the broken to the whole workings; and (2) that an explosion shall not take the air off the men at the faces of work, or reverse its direction.

The author does not hesitate to assert that three-fourths of the explosions that occur, and that result in such a lamenta-

ble destruction of life and property, are caused solely by the neglect of the former of these conditions, and are therefore preventable; and that a large proportion of the deaths that result are due to the neglect of the latter conditions; for in most cases fewer men are killed by the direct effects of the explosion than by the after-damp. It does, indeed, seem strange that such an ignorant mode of distributing the air should still be commonly adopted. When the ventilation is in uneducated hands we may attribute the practice of the pernicious system to ignorance and want of skill; but when, as is sometimes the case, we find the practice perpetuated under the authority of men eminent in their profession, we are forced to believe that a criminal economy is at the bottom of the matter.

The second condition is scarcely of less importance than the first, as it deals with the effects of an explosion should such an accident occur from any unforeseen cause. The ventilating current will always take the shortest course to the upcast shaft. If, in consequence of an explosion, the doors or stoppings are injured, a large portion of the workings may be left entirely without air at a time when it is most needed, namely, when the passages are foul with the after-damp or carbonic acid gas produced by the explosion. To prevent such an occurrence the distribution should be so arranged as to preclude the possibility of the current of air being diverted from its proper course before it has left the working places, or of being stopped altogether by an injury to the return passage. All permanent stoppings should be built of brick or stone and well plastered; they should also be well backed, especially those by the side of the main ways, which should have five or six yards of stowing behind them. Whenever a crossing is necessary for the return it should, if possible, be by a stone drift over or under the main way. The additional cost thus incurred would be more than compensated by the additional security obtained. Were all these precautions duly observed, mining would be freed of half its perils. A strict supervision would be all that was necessary to protect the mine against the danger of an explosion occasioned by any but unforeseen causes. Such supervision is indispensable in all cases to ensure the proper quantities of air being apportioned to the several districts, and the needful precautions constantly taken to maintain a steady uniform current of air. Without this the best system must prove ineffectual.

DISCUSSION.

Mr. Baldwin Latham said he would offer a few remarks in order to open the discussion, but his observations would be on the general question of ventilation rather than with particular reference to coal mines. He had certainly given some attention to the ventilation of coal mines when studying the ventilation of sewers; but he had found that the system of having one downcast and one upcast shaft for the ventilation of coal mines was comparatively easy to carry out, but that it was not at all applicable to sewers. From his examination of a large number of coal mines he was convinced that the observations which had been made by Mr. André in his paper were of very great value. The paper did not touch upon the particular means which were adopted for the ventilation of coal mines, but it simply brought forward broad facts which it would be well for all interested in such matters to bear in mind, and which showed that there never could be safety without a superabundance of fresh air. There was not sufficient attention paid to the ventilation of a mine as the workings were worked out, or as the material was extracted. In his opinion a new mine required far less air than one which had long been at work. The little passages which were shown in the diagrams were air-channels; and in a new mine the cubic capacity of those channels would be comparatively small; but when the mine was worked out the cubic capacity became greater. When gases escaped or blowers occurred, the passages and goaves acted as gas-holders by means of which gas could be accumulated. In an old mine the same intake and the same volume of air passed through it as in a new mine, although the cubical capacity in the old mine was greater. The chances were that in old mines the whole area might become occupied with gas which, by the admixture of the atmospheric air, in limited quantities, would be rendered explosive.

Instead of being diminished as the mine was worked out, and the cubical capacity of the mine became greater, the amount of air ought to be increased, and not only so, but adequate mechanical arrangements ought to be introduced by which the air could be conducted through the vacant spaces so as to completely ventilate the mine.

It was a disputed point whether natural or mechanical means ought to be adopted for ventilating mines. By mechanical means, he meant the use of steam as a mechanical power, for either driving air into the mine or sucking air out. The plan of driving air into a mine was called the plenum system, and the plan of drawing air out was called the vacuum system. The natural system of ventilation consisted of those methods in which the air of a mine was heated by ordinary combustion, so that they got a column of heated atmospheric air which was considerably lighter than an equal column of cooler air, and by this difference in the weight of respective columns of air motion was produced. Air upon being heated dilated $\frac{1}{490}$th of its own bulk for every degree Fahrenheit. Hence he fully corroborated the statements of Mr. André, that the passage for the exhausted air required to be far larger than the passage for the intake air. Air always passed into a mine at a temperature far lower than that of the air some hundreds of yards below the surface of the earth. The air of a furnace was applied in order to heat air in excess of atmospheric heat, and create that current of air which is necessary to aerate every part of the mine. A cubic foot of air heated 50 or 60 or perhaps 80 degrees would occupy a far larger space than it originally occupied when it entered the mine. This caused the necessity for increasing the size of the air-passage for all air which had once passed through the mine. If this was not done there would be a contraction, and contraction meant waste of force, and it also meant retardation of ventilation. Further, it was possible when there was a contracted passage that from some sudden cause, such as the explosion of gunpowder in the mine, the whole current of ventilation might be changed in the opposite direction. Therefore it was needful in all cases of mine ventilation to make the passage of the air as easy as possible, from the place where it entered to the place where it passed out. If the passages were uniform throughout, some circumstances might momentarily change the direction of the air, and the result to those who were laboring in the mine might be an immense loss of life. Hence the necessity of producing enlarged passages for the easy exit of the air that had been used in the mine. Air would always take the shortest passage. We might make passages for it, but it would not follow the route prescribed for it if it could get away by any shorter cut.

THE DISTRIBUTION OF AMMONIA.*

By Dr. R. ANGUS SMITH, F. R. S., &c.

From "Journal of the Society of Arts."

If organic matter is everywhere, ammonia is everywhere possible, and if that matter is decomposing, ammonia is everywhere. This is the general statement which this paper illustrates. It is now many years since it was observed by me that organic matter could be found on surfaces exposed to exhalations from human beings; but it is not till now that the full significance of the fact has shone on me, and the practical results that may be drawn from it in hygiene and meteorology. These results are the great extension of the idea that ammonia may be an index of decayed matter; the idea itself has been used partly and to a large extent, as illustrated in my "Air and Rain." The facts now to be given enable us to claim for it a still more important place. The application seems to fit well the conditions already examined, and by this means currents from fou

* Paper read before the Manchester Literary and Philosophical Society.

places have been readily found. This does not apply to the substances which may be called germs, whether it be possible to see them or not, because these are not bodies which have passed into the ammoniacal stage, although some of them may be passing; those, for example, which are purely chemical, and exert what we may call idiolytic action. This word may serve to mark this peculiar action, which was left by Liebig unnamed; he used the vague term invented by Berzelius, namely, catalytic. I have elsewhere recognized the two classes of germs, instead of any disputed one, without naming them.

It is now many years since Liebig first surprised me by saying that iron ores and aluminous earths were capable of taking up ammonia, and if they were breathed upon we were able even to smell that substance. He, much about the same time, made numerous experiments, in order to find the ammonia of the atmosphere, and to measure its amount in rain. The result for science was great, and Professor Way continued the inquiry for the Royal Agricultural Society. Dr. Gilbert, F.R.S., amongst his many labors in the department of agricultural science, has made this inquiry into ammonia of rain in still later times; but I shall not at present quote his results, as this paper does not intend to go fully into the subject, but rather to indicate its magnitude and importance. The first paper I ever read to this Society was on the ammonia found in peat: I was unable then to see the extent of the subject.

I shall give parts of the fuller paper without the long tables of results.

Ammonia must ever be one of the most interesting of chemical compounds. It comes from all living organisms, and is equally necessary to build them up. To do this, it must be wherever plants or animals grow or decay. As it is volatile, some of it is launched into the air on its escape from combination, and in the air it is always found. As it is soluble in water, it is found wherever we find water, on the surface of the earth or in the air, and probably in all natural waters, even the deepest and most purified. As a part of the atmosphere it touches all substances, and can be found on many; it is, in reality, universally on the surface of the earth, in the presence of men and animals, perhaps attached, more or less, to all objects, but especially to all found within human habitations, and, we might also add, with equal certainty, the habitations of all animals.

If you pick up a stone in a city, and wash off the matter on the surface, you will find the water to contain ammonia. If you wash a chair, or a table, or anything in a room, you will find ammonia in the washing; and if you wash your hands, you will find the same; and your paper, your pen, your table-cloth, and clothes, all show ammonia, and even the glass cover to an ornament has retained some on its surface. You will find it not to be a permanent part of the glass, because you require only to wash with pure water once or twice, and you will obtain a washing which contains no ammonia. It is only superficial.

This ammonia on the surface is partly the result of the decomposition of organic matter continually taking place, and adhering to everything in dwellings. The presence of organic matter is easily accounted for, but it is less easily detected than ammonia. It is probable that the chief cause of the presence of ammonia on surfaces in houses, and near habitations, is the direct decomposition of organic matter on the spot. If so, its presence, being more readily observed than organic matter itself, may be taken as a test, and the amount will be a measure of impurity. A room that has a smell indicating recent residence will, in a certain time, have its objects covered with organic matter, and this will be indicated by ammonia on the surface of objects. After some preliminary trials, seeing this remarkable constancy of comparative results and the beautiful gradations of amount, it occurred to me that the same substance must be found on all objects around us, whether in a town or not; I, therefore, went a mile from the outskirts of Manchester, and examined the objects on the way. Stones that not twenty hours before had been washed by rain showed ammonia. It is true that the rain of Manchester contains it also; but, considering that only a thin layer would be evaporated from these stones, it was remarkable that they indicated the existence of any. The surface of wood was examined—palings, railings, branches

of trees, grass (not very green at the time), all showed ammonia in no very small quantities. It seemed as if the whole visible surface around had ammonia. I went into the house and examined the surfaces in rooms empty and inhabited, tables, chairs, ornaments, plates, glasses, and drawing-room ornaments. A (Parian) porcelain statuette, under a glass, showed some ammonia; a candlestick of the same material (but uncovered) showed much more; the back of a chair showed ammonia, when rubbed with a common duster, very little. It seemed clear that ammonia stuck to everything.

If, then, ammonia were everywhere, the conclusion seemed to be that it was not at all necessary to do as I had been doing, namely, wash the air so laboriously; it would be quite sufficient to suspend a piece of glass, and allow the ammonia to settle upon it. For this purpose small flasks were hung in various parts of the laboratory, and they were examined daily. The flasks would hold about six ounces of liquid, but they were empty, and the outer surface was washed with pure water by means of a spray bottle; it was done rapidly, and not above 20 c.c. (two-thirds of an ounce) of water was used. This was tested for ammonia at once with the Nessler solution. The second washing produced no appearance of ammonia, done immediately. Ammonia could be observed after an hour and a half's exposure, at any rate, but I do not know the shortest period. The results of the washings were as follows; they are the average of 34 experiments for some, and 17 for others; in all 238 experiments:

	Height from floor.		Ammonia	Height from floor.		Ammonia
	ft.	in.	M.gms	ft.	in.	M.gms
Front laboratory.	7	3	0.013	4	2	0.019
Second landing..	6	0	0.032			
Balance-room....	5	1	0.015	0	8	0.009
First landing....	4	10	0.007			
Back laboratory.	4	5	0.010	0	6	0.010
Entrance lobby..	6	5	0.007			
Office..........	4	7	0.003			
Back yard......	4	8	0.036	0	7	0.042
Back closet.....	2	3	0.105			
Midden.........	—		0.572			

The first three belonging to the working laboratory are not very regular, as we might suppose, but they never rise very high, nor do they sink to the lowest. The rest, except the second, keep a remarkable similarity, and the differences are very great. In the second there is a disturbance caused by sweeping the floors. On the other days it was requested that everything should be kept still. This of course brings in a practical difficulty, and limits the use of the test to cases where care can be used and thoughtful observation, since there are many ways by which dust may be made to interfere, even although the act of sweeping should not take place. The house experiments gave similar gradations.

The result seems to be that a piece of glass, of a definite size, hung up in any place, will receive deposits of ammonia, or substances containing ammonia, in a short time; and by washing the ammonia off with pure water, and testing it with a Nessler solution, it may be seen whether there is too much or not. It is the simplest test for ammonia yet found. Its discoverer deserves great thanks. It must not be forgotten that we may have ammonia in very different conditions; it may be pure, or it may be connected with organic matter. This mode of inquiry is better suited as a negative test to show that ammonia is absent, than to show what is present. When ammonia is present there may be decomposing matter; when absent there is not. I am hoping to make this a ready popular test for air—a test for sewer-gases, for overcrowding, for cleanliness of habitations, and even of furniture, as well as for smoke and all the sources of ammonia. Of course it must be used with consideration, and the conclusions must not be drawn by an ignorant person.

How far it may be used as a test of climate is a matter to be considered.

After this I made another series of trials with air. Nesslerising the washings at once, and not after laborious distillings, as in former cases; the results are very valuable, showing that we obtain comparative quantities in this way.

The amount of ammonia obtained in this ready way does not give exactly the same results as the more laborious methods which I have used, but it may be taken as the most convenient. It must be observed that the amount rises

exactly where you might expect more organic matter to exist. The lowest is from Prince's road, outside the town, and almost half a mile from the extreme of the Manchester houses. The next is obtained from an empty yard behind my laboratory, but it is still pure because there was wind and rain; and any one who observes how unusually pleasant it is to breath air even of a smoky town during wind and rain will not be surprised. I have not yet, however, had the purest air. I shall require to make a campaign on the moors, hills and seas, before I can give numbers for this. I have not even obtained the best given on land at a distance from manufactures. All this will be done in time.

In my office the amount is larger than outside, but the air is not so bad as it is in front, and not so good as sometimes in the front where it is open. From the back of the laboratory, during fog, the ammonia was much higher, but during one day it was excessive, and a special examination of it was made in several streets. The highest amount was obtained at the front of the Cathedral, about midday, on the 8th of February, 1878, when the amount was 1.25, or 14½ times more than it had been found in Prince's Road, showing a considerable range:

	M.grms. of ammonia per per cubic meter of air.
Prince's Road	0.086
Open yard during rain	0.119 and 0.102
Front of laboratory	0.167 ordinary
Office	0.167
Front and back during fog	0.476
Close shut up room	0.413
Closet outside	0.800 to 0.900
Densest part of fog	1.25

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers.—The papers published by the Society in the "Transactions" since our last issue are:

No. 159. On the Theoretical Resistance of Railway Curves, by S. Whitney.

No. 160. On the Cause of the Maximum Velocity of Water Flowing in open Channels being Below the Surface, by James B. Francis.

No. 161. The Flow of Water in Pipes under Pressure, by Charles G. Durragh.

International Congress on Civil Engineering.—The programme of the International Congress on Civil Engineering at Paris, in 1878, is of importance not only as a guide to inquiry and discussion, but as a synoptic view of that branch of practical science as regarded in France. It consists of nine sections, which are as follows:

Section 1. *Mines and Metallurgy.*—1. Steel: New Modes of Making Steel; 2. Explosions of Firedamp; 3. Transport in Working Mines; 4. Mechanical Working of Coal; 5. Process of Sinking Wells and Shafts.

Section 2. *Agriculture and Rural Engineering.*—1. Steam Culture; 2. Utilizing Hydraulic Resources; 3. Reclamation of Land fit for Cultivation; 4. Machines serviceable for Harvesting; 5. Economical Transport in Farms.

Section 3. *Machines.*—1. Steam Power; 2. Accumulators; 3. Associations for Supervision of Steam Engines; 4. Unification of the Dimensions of the Parts of Machines; 5. Choice of the Fittest Metals to adopt for the different Parts of Machines.

Section 4. *Roads, Rivers, and Canals.*—1. Inundations: Means of Checking them; 2. New Descriptions of Metal Bridges; 3. Utilization of Roads and Banks for the Establishment of Railways; 4. Comparison of the Different Modes of Paving Towns; 5. Dams for Rivers.

Section 5. *Railways.*—1. Economical Railways; 2. Motor Machines for Tramways; 3. Material Improvements to Introduce into the Passenger Service; 4. Perfecting the Way; 5. Employment of Steep Gradients.

Section 6. *Navigation, Fluvial and Maritime.*—1. Compound Engines in Marine Navigation; 2. Resistance of Hulls; 3. Haulage of Boats: Life-boats; 5. Rolling and Pitching.

Section 7. *Public and Private Constructions.*—1. Supply and Distribution of Water in Towns; 2. Drains; 3. Ventilation of Edifices; 4. Mechanical Perforation of Galleries and Tunnels; 5. Foundations of Great Works.

Section 8. *Industrial Physics and Chemistry.*—1. Utilization of Artificial Cold: 2. Lighting large Workshops; 3. Pneumatic Telegraphs; 4. Industrial Employment of Explosive Substances; 5. Gas Stoves.

Section 9. *Different Industries.*—1. Machines for Domestic Use; 2. Fabrication of Paper, from the point of view of the Paucity of Rags; 3. Recent Progress of Spinning and Weaving; 4. Cements, their Manufacture and Use; 5. Character of Textile Fabrics.

IRON AND STEEL NOTES.

Messrs. Hoopes & Townsend, manufacturers of iron bolts, nuts, rivets, etc., have issued a pamphlet which contains much valuable information. It is largely made up of reports by Professor Thurston on tests made under his supervision upon cold punched and hot pressed nuts.

The results are beautifully tabulated and the reports are illustrated by cuts of the first order of excellence.

The paper on the flow of metals by Tresca is added with illustrations. This paper explains how in cold punching the strength of the metal is preserved.

The exhibit at the Centennial of this celebrated firm proved the excellence of their method.

Improvement in the Manufacture of Steel.—The following description of an improvement in the manufacture of steel has been sent to the "Bulletin of the American Iron and Steel Association" by Mr. W. Dougherty of Cedar Lake, New Jersey, the patentee. "Steel cast by the ordinary process is rarely free from seams, soft places, honeycomb, &c., thereby causing considerable loss to the manufacturer or purchaser. The object of my ininvention is the production of steel free from defects. The invention relates to the casting of the ingots in sheet metal moulds or cases of such thickness as will be brought to a welding heat without chilling the surface of the ingots, so that the steel and case may cool and shrink simultaneously, and the case become thereby welded to the steel, and thus exclude the atmosphere from the latter and thereby prevent such imperfections as result from the shrinking away of the steel from the mould. I make the case of any form or size the ingot is required to be, taking care not to have the sheet out of which it was formed of greater thickness than will be brought to a welding heat without cooling the surface of the melted steel when poured into it, so that the case and ingot may cool simultaneously and a complete welding be produced. The sheets of which the cases are formed should not be too thick, otherwise a welding will not take place, and the thickness should vary according to the size of the case; consequently, for casting small bars of steel, say two or three inches in diameter, the thickness should not be more than the sixteen-wire gauge. The steel thus encased when put into the furnace for heating, having its surface completely protected from the atmosphere, retains the carbon in its imperfect places as well as in the solid parts of the metal, and consequently, when subjected to the action of the rolls or hammers, a complete welding of the metal is produced, and a homogeneous mass of the metal is the result. A portion of the metal case or mould is burnt or wasted away during the process of heating the steel. The remainder, being thin, is taken off, or nearly so in the working of the metal, so that no inconvenience results from the steel being encased. In the usual method of casting ingots in thick cast iron moulds the moulds chill the surface of the ingot, causing a deep hole in the upper end, which is technically called piping. This occasions the necessity of breaking off the end of the ingot, and thus causes a loss of from ten to twenty five per centum of the steel. In casting by my process, the mould or case, being thin, does not cool the melted steel, and being brought to a welding heat by the latter, as above specified, the steel cools slowly and uniformly with it closing in to the centre of the ingot, and thus avoiding the piping incidental to the usual mode of casting in thick moulds. I claim as my invention the method of casting steel in wrought iron or other metallic cases when the latter is of such thickness as to admit of the heat of the melted steel completely welding the case to it, substantially as and for the purpose above set forth."

The Preservation of Iron Surfaces.—Mr. George Bower, of St. Neot's, has lately perfected a process for coating iron with the magnetic oxide, not however by means of superheated steam, but by the employment of heated air. Mr. Bower conceived the idea that the oxygen as it exists in the atmosphere would serve the same purpose equally as well as, if not better than, the oxygen as it exists in water or steam. He therefore made some elaborate experiments which conclusively proved his supposition to be correct.

Having satisfactorily established this fact Mr. Bower experimented on a large scale, and at length succeeded in giving practical shape to his process. During his experiments Mr. Bower had an idea that the hot blast as used in the production of pig-iron would not only heat iron exposed to it to the required temperature, but that it would at the same time supply the oxygen for the formation of the magnetic oxide. By the courtesy of Messrs. Cochrane, of Dudley, he was enabled to prove this. A bar of iron of square section exposed to the action of the hot blast for about twelve hours was found to be thoroughly coated with the magnetic oxide. This coating, it is stated, has perfectly resisted the oxidising action of moist air under the most trying conditions. The method of procedure in practice is to expose the iron articles in a retort or chamber, the temperature of which is raised to a point dependent upon the ultimate use to which the articles are to be put, and which ranges between a dull and a bright red heat. Air is then introduced and imprisoned in the chamber, a fresh supply being fed in at stated intervals. The articles under treatment are exposed to the combined influence of heat and air for periods which vary according to the nature of the objects, the result being the formation upon them of the protective coating of magnetic oxide.

In carrying out the process at his works Mr. Bower uses an iron chamber which is built into a furnace; it is, in fact, set very much in the same way as gas retorts are. The chamber is about 7 feet long by 2 feet in height and width, and its mouth is closed by a carefully fitting lid having two holes in it. One of these holes serves as an inlet for the air whilst the other is the outlet. The inlet aperture has screwed into it a long tube which reaches nearly to the further end of the chamber. This pipe is connected with an ordinary gas holder filled with air fitted with a tap, as is also the outlet pipe, which is of course very short. The articles to be operated upon are placed in the chamber and the cover is luted and screwed tightly on. The temperature is then raised to the required degree, for ordinary purposes a dull red heat being employed. At the end of every hour a sufficient quantity is driven into the retort to sweep out the deoxidised air, after which the inlet and outlet cocks are again closed. After a certain time which, as we have stated, varies with circumstances, the articles are withdrawn, and are found to have received a perfect coating of oxide. The color of this coating is exceedingly pleasing to the eye being a grey or neutral tint of varying depth, that is to say, ranging between a light and dark shade. Some sam-

ples we have seen possess a very delicate color and one which renders further ornamentation by means of paint quite unnecessary. Notwithstanding this delicacy of tint we are informed that exposure to the influences of atmosphere and weather, and the application of severe tests, have no detrimental effect upon it. The apparatus used by Mr. Bower is at present only experimental, that is, it is not adapted either by size or arrangement for commercially working the process. Having, however, demonstrated its practicability on a reasonably large scale, we presume its adoption on a working basis will soon follow. In such case it is intended that the draught of the shaft leading from the furnaces shall be the agency by which the air will be drawn into the chamber. Moreover, the capacity of the chambers will vary with the size of the articles to be coated, and they will be run into the chambers on tracks so as to admit of their ready removal from, and the quick recharging of the chambers.

We may mention that although Mr. Bower's process answers particularly well for cast iron it is not at present so well suited for wrought iron. Mr. Bower, however, is now working out some slight modifications, by means of which he expects to be able to attain equally satisfactory results with both wrought iron and steel. The cost of thus coating the iron is estimated at about £1. per ton, whether the ton be a solid mass of that weight, or whether the weight be made of a large number of small articles. This estimate, however, may be altered by the light of practice, but provided it is not greatly exceeded, and provided also that the process is as easy of application, and the coating as permanent, as it appears, to be, there is a promising future before Mr. Bower's ingenious process.

RAILWAY NOTES.

Orenburg and Central Asia.—A Berlin correspondent announces that Russia is making an effort to secure the early construction of the railroad from Orenburg into Central Asia—200 German miles. The money required will be raised by a loan.

Victorian Railways.—At the close of 1876 Victoria had 702 miles of line open for traffic, and there were further 259 miles in course of construction. Up to December 31, 1876, the expenditure on the Victorian railways, inclusive of rolling stock and plant, was £13,710,364. the approximate average cost per mile was £19,558, which will be reduced to £15,440, when the new lines are finished. The rolling stock comprised 61 passenger engines, 63 goods engines, 210 carriages, and 2,194 wagons, vans, cattle trucks, &c. For the year July 1, 1876, to June 30, 1877, the receipts were £1,074,497. For the previous year they were £994,767.

A Half-Finished Railway.—The Chilian Government has concluded a provisional contract for the completion of the Chili and Southern Railroad, one of the enterprises in which the government was induced to embark some time since. The road, which is 400 miles in length, is in operation, in spite of the fact that no stations have been erected, and that the permanent way has yet to be ballasted. No less than forty rivers lie across the path of the line, while at present only ten bridges have been constructed, those bridges being of wood, which the contractors will not guarantee to stand any lengthened strain. Where there are no bridges the passenger are conveyed across the rivers, and they then re-embark in fresh cars on the other side.

St. Gothard.—The proposal for a supplementary grant in aid of the St. Gothard Railway has been submitted to a popular vote in the canton of Zurich, and has been rejected by a large majority. It is believed that the decided line taken in Zurich will give strength to the growing impatience of seemingly unlimited outlay, which is felt in other cantons, and that not only will the cantonal grants in aid be refused, but the national subvention that has been proposed, will also fall to the ground. In that case the undertaking must be suspended for want of capital, unless the governments of Germany and Italy, which are already pledged to contribute a very large sum, undertake to supply the whole of the deficit. We are afraid, therefore, that the prospects of the completion of the St. Gothard Railway—we do not say by 1880, the date originally fixed, but within any reasonable period—are gradually vanishing. Already large sums have been expended, chiefly upon the construction of the celebrated tunnel between Geschenen and Airolo, but unless a much larger outlay be now faced, all that has been done since 1871 will go for nothing.—*Iron.*

ENGINEERING STRUCTURES.

The Suez Canal.—The transit revenue of the Suez Canal Company amounted for the first five months of this year to £651,817, showing a reduction of £33,992, as compared with the corresponding period of 1877. This result was attributable to the reduction made in the tolls in April, 1877.

The New Eddystone Lighthouse.—It is announced that the Trinity Board, after six weeks' consideration, have decided to build the new Eddystone Lighthouse themselves, and not under contract. The estimate of the Board's engineer was £90,000. There were three tenders, the lowest, that of Mr. Pethick, of Plymouth, being £105,000.

The *Western Morning News* gives the following description of the proposed new structure: The first point which offered itself for consideration was obviously that of the precise site for the new work. Smeaton's tower, (the present building) was, of course, erected on the very site of its predecessors—the wooden, or mostly wooden, structure of Rudyerd, which was completely destroyed by fire; and the fantastic building, also of wood, put up by Winstanley, as the first occupant of the rock, and which, together with its author, was utterly annihilated in the great storm of the

26th of November, 1703, after a brief but useful existence of three years.

The "House Rock," as it is called, upon which the present tower is built, stands not alone, but is only one and the highest of a group of rocks and reefs, projecting their jagged summits in the range of tide between low and high water. These comprise the House rock and reef, the South rock and reef, the South-east reef, the East Rock, and a detached spit, the North-east rock. The position selected for the new tower is on the South Reef, about 100 feet away from the existing lighthouse, across the gut or channel, and in a south-easterly direction. It has the advantage of partial protection, towards the west and south-west, by the House Rock and reef, but the disadvantage of being considerably lower in elevation. No portion of the site rises above the half-tide level, and the lowest parts, where the foundation courses of the new structure are to be laid, lie 4 feet below the low-water level of an ordinary spring tide; whereas the rock whereon Winstanley, Rudyerd and Smeaton carried on their operations, so far as relates to the immediate site of their labors, was entirely above the half-tide level, and its summit at the present landing-place is not covered at high water of ordinary spring tides. It will readily be understood that this constitutes a material aggravation of the difficulties and hazards, already great, of this new and arduous enterprise. For not only is the exposure to the action of surf and ground-swell more than proportionately increased, but the duration of the already too limited time within which it is possible to carry on work "in the dry" is most seriously shortened; and no inconsiderable portion of the basement must be executed entirely under water. The retention of the old tower during the construction of its successor is a *sine quâ non.* The lower level of the foundation for the new work has also exercised an influence on the form, proportions, and dimensions of Mr. J. N. Douglass's design, which is not only very much larger than that of Smeaton's, but varies considerably therefrom. Fundamentally the same general form is to be adopted; and, technically speaking, the shaft of the tower is a concave elliptic frustrum,—realised in Smeaton's original conception as the bole of an oak,—but, in order to give weight and solidity to the substructure, with corresponding power of resistance to the violence of the waters, the lower courses of masonry, up to and inclusive of the twelfth, are to be perfectly cylindrical in form up to the level of about 3 feet above the high-water level of ordinary spring tides. At this point there is a diminution of more than 8 feet in diameter, forming a commodious landing platform, whence springs the shaft proper of the tower. The diameter assigned to this cylindrical base is 44 feet, and that of the tower at its springing is between 35 feet and 36 feet, at a height of a little over 22 feet above the foundations. The circular shaft attains its smallest dimensions (18 feet 6 inches diameter) at a height of about 134 feet above the rocky bed of its foundation; swelling out, with a bold and graceful cavetto, to an enlarged diameter of 23 feet maintained up to the level of the gallery-course or lantern floor, at a total height of 142 feet above the base of the light-house, and 122 feet 6 inches above the level of high water of ordinary spring tides. The magnitude of this noble light-tower will be at once apparent by comparison with the similar dimensions of its existing predecessor. Smeaton's shaft diminishes from a diameter of 34 feet at the foundation-course to 26 feet at the level of high water ordinary spring tides; and thence to 20 feet at the entrance door, and 15 feet at the top, the gallery-course being but 61 feet above high-water mark, and the lantern-floor about 7 feet higher. Thus the new light will be displayed at an elevation 55 feet greater than that of the old one, and its range of visibility and efficiency will be proportionately extended. It would be superfluous, in regard to an as yet unexecuted work, to describe minutely all the proposed details of its construction; but some few of the general features of the design may be glanced at with interest. The structure is to be built entirely of granite, and to be entirely solid (except a small water-tank) up to the level of the entrance-floor, at about 22 feet above the landing-platform; the access from low-water mark being by an outside step-ladder, formed of gun-metal cleats, recessed in the granite below the platform, and projecting from the surface of the tower above that level. The foundation is to be formed by cutting away the rock in benchings or steps, for the first four courses, all the stones which bed on the rock being secured thereto by metal bolts. Throughout the entire structure every individual stone will be closely united, or bonded in to those surrounding it, by solid dovetail projections, fitting into corresponding recesses; and each course of stones is similarly to be connected with those above and below it; so that in this manner, when set in Portland cement, the entire mass will require almost the homogeneity and strength of the solid granite rocks from which its component elements were quarried, as has been amply demonstrated by experience. The hollow upper portion of the tower will be similarly built, the rings being formed of single stones running through from the inside to the outside of the shaft. The internal diameter, as proposed, varies from 11 feet 6 inches to 14 feet, and the thickness of the ring from 8 feet 6 inches to 2 feet 3 inches. This part is to be divided by arched granite floors into nine stories, apportioned as stores, coal, oil, crane, living, bed, and service rooms. The door and window openings will be provided with gun metal doors, sashes, and shutters; and the general fittings of the tower are proposed to be of the same first-class, solid, and expensive character,—therein lying true economy, from the very situation, nature, and purpose of the lighthouse. Summing up the total quantity of the granite in the proposed new tower, it is approximately something less than 69,500 cubic feet, giving to the mass a total weight of about 5,150 tons of masonry. The metal-work in cast, malleable and wrought iron, in gun-metal, Muntz-metal bolts, copper, and brass and other materials will make up a gross total of about 50 tons more, or 5,200 tons

in the whole. This great mass will have to be wrought, set up, and fitted together on shore, taken down, loaded in vessels, transported by sea to the Eddystone rocks,—a distance of fourteen miles from Plymouth—and there unloaded, hoisted and built into position, at a mean height of 43 feet above the level of low water of an ordinary spring tide. The time allowed for the completion of the work is five years, giving an average of 1,030 tons to be erected in each year, practically limited to the summer season, so far, at least, as the actual work at the rock is concerned, inasmuch as during the winter half of the year it is impossible to carry on operations of this kind at all; and it may be added, indeed, that the work can only be executed intermittently even during the summer months.

ORDNANCE AND NAVAL.

THE GARRETT TORPEDO BOAT.—We are, this week, in a position to give details respecting the Garrett torpedo boat, the launch of which, at Birkenhead, on the 6th inst., was tersely announced in last week's *Iron.* She is a small but perfect specimen of the larger boat which would be required for some of the more difficult kinds of submarine work. It is cigar-shaped, and runs rather abruptly to sharp points at both ends, the total length from point to point being 14 feet and the width across the center 5 feet. It has been constructed of plates of iron 3-16th of an inch in thickness, riveted together, and weighs, inclusive of ballast, about 5 tons. To the outside a coat of lead-colored paint has been given, and this accomplishes the object aimed at in concealing almost all outlines except those which rise above the surface of the water. When floating at its normal or resting level, the position of the boat is revealed by a "conning tower," which rises for about 2 feet from the center of the cigar and forms a manhole, through which access is obtained into the interior. In the sides of the tower, which is of square shape, are round glass windows for outlook, and two brass caps, the uses of which will be explained hereafter. The balance of the boat is preserved, and the tower maintained in an upright position, by a leaden keel nearly 2 feet bread and about 2 tons in weight. An ordinary four-bladed screw-propeller revolves at one end of the boat mounted on a shaft, which communicates with the interior through a water-proof chamber. The steering power is obtained by means of rudders worked by suitable gear from within. These outward appliances and accessories, however, add little to the apparent bulk of the boat, most of them being almost invisible even when the craft is resting at the surface. Little unnecessary and unoccupied space is to be found within, although there is ample room for the movements of the operator. Upon the latter falls the task of propelling the boat through the water, and he causes the screw to revolve by means of an ingenious combination of treadle and fly-wheel. Of the more important features of the interior are some water-tanks located at each end of the boat, and a force pump, with powerful lever handle and tap, within easy reach of the manipulator. This is the actual machinery of descent as distinguished from that of propulsion. Once within and assurred that the manhole cover has been securely closed down upon him, the operator descends to the desired depth by turning the tap to his right. This admits into the tanks a quantity of water, which, overcoming the buoyancy of the boat, causes it to sink rapidly. The descending motion may be slackened, as it may be arrested, by the same method. But to cause the boat to ascend it becomes necessary to use the force pump. This appliance, by expelling the water from the tanks, restores the lost buoyancy, and the boat ascends with a rapidity exactly dependent upon the amount of force employed. It may sink to a depth of 30 feet, or may linger 6 feet below the surface, and it can be moved forward or backward at any desired distance from the surface. The details of the inventor's method of purifying the air within the boat, in order to make it supportable during a close confinement of perhaps several hours, are at present secret, and form, without doubt, a main feature of the scheme. In his descent the operator takes with him a number of iron tins of compressed air, a bottle of oxygen, and a number of tin cases containing a mixture of chemicals. A case is strapped to his back after the manner of a knapsack, and when seen at work through one of the windows, he is observed inhaling air, and as rapidly sending it through a tube which enters his mouth and passes over his head to the case on his back. The air passes through the chemicals, is purified, and again enters the lungs of the operator, to be again sent through the tube for purification. When a case is exhausted of its purifying properties another must be taken up and mounted. But these are not the only duties, apart from the mere working of his vessel, which fall to the lot of the submarine traveler. Oxygen must be added from time to time, and danger is sure to ensue if he forget the important rôle played in the safe navigation of the boat by the compressed air. He is careful to maintain as far as possible a mean between the outward pressure of the water, which increases with the depth, and the inward pressure of the air, which he is at pains to augment when necessary by opening one of his cases of air. In addition to this, he is supposed to keep a bright lookout for all objects lying in his way, or moving in his vicinity. If attacking a man-of-war lying at anchor, he descends to the necessary depth, moves cautiously forward, and when close to the mooring or other chain unscrews the two caps in front of his tower. This operation gives entrance to a quantity of water, but as the holes are merely flanked internally by a long flexible arm-sleeve of stout material closed at the inner end, no water actually enters the boat. Viewed from within, these sleeves would look like long pendent stockings hanging down inside full of water. The operator pushes his arm through them, turning them as it were inside out, as he pushes them through the holes into the water around his vessel. Using each as a sort of glove, he attaches a hook hanging outside his boat to the

chain of the man-of-war, puts on his caps, and moves his craft quickly to the rear. The motion draws taut a loop line, and runs a torpedo from his rear up to the chain, where it is exploded either by the shock of contact or by electricity. The weakest part of the hull of a large vessel might thus be sought out and attacked with tremendous effect.

When the boat is below the surface artificial light is of course necessary Mr. Garrett has discarded all methods capable of adding impurity to the atmosphere. He uses a lamp formed of two Gassiot (glass) tubes, partly exhausted of air. When a current of induced electricity is passed through these tubes a soft bluish light is the result, and there is sufficient illumination for all the necessary operations. The ordinary electric-light, of much brighter flame, would have to be employed for purposes of exploration or observation without, and the inventor has this extension of his scheme in contemplation. Electric communication between the boat and, say, a steam launch far in the rear, is provided by sending and return wires in one strand passing through a well-stopped hole in the tower, the telephone and an ordinary electric call-bell being sufficient for the purpose.

The experiments were, generally speaking, of a very successful character. Manipulated very cleverly by the inventor, the boat sank and rose to the surface, moved forward above, and was propelled below many times during the five hours occupied by the inspection. The strange appearance of the vessel was a matter of much remark. When floating with its tower just level with the surface of the water it resembled the snout of some marine monster, an impression which was strengthened when it blew up volumes of water after the manner of a whale. Mr. Garrett remained below on one occasion an hour and a-half without requiring any assistance, and so well had the purification of the air been accomplished that an improvement in the quality of the latter was noticed on the manhole being removed. Subsequently the inventor remained below a little over an hour, intending to illustrate his method of attaching the torpedo and of using his arms outside the boat. His inability to do so illustrates the precariousness of and danger of even the new method of submarine navigation. He had no sooner unscrewed the caps below, admitttng the water into the sleeves, than he discovered a leak in one of them, through which the water spirted, threatening momentarily to enlarge the hole, and fill the boat. He had presence of mind enough to seize and twist the arm, and while stopping the leak by this means, to work the force pump with the other hand, and thus raise himself to the surface. During the greater part of the time, during which the experiments lasted telephonic communication was maintained between the boat and the steam launch conveying the party.

The present speed of the Garrett torpedo boat is about 4 or 5 knots an hour. The specimen under notice, however, is designed for the use of one man. The inventor contemplates a boat of proportionately greater strength and size that may accommodate and be worked by three men. An improvement of the means of propulsion is also in view, the most suitable being gas or compressed air; this would increase the speed to a maximum of at least 10 knots, while increased speed would give increased command over the steering of the boat. The vessel used on this occasion was merely an experimental one, but quite strong enough to bear the pressure met with at a depth of 30 feet. A larger vessel would have more liberty in this respect, but as most of the purposes of such boats may be accomplished within a comparatively few feet of the surface, the capacity to descend to great distances is by no means absolutely necessary. Mr. Garrett has already been in communication with the Admiralty on the subject of his boat, and we understand that he is about to report the particulars of his invention to that board. He attaches primary importance to the chemical as compared with the mechanical part of his invention, for which he has already taken out a provisional patent.

The new boat, with all its machinery, was made by Messrs. Cochran and Co., engineers and ironfounders, Birkenhead, the work of construction occupying about two months.

BOOK NOTICES

Slide-Valve Gears. By Hugo Bilgram, M.E. Philadelphia: Claxton, Remsen & Haffelfinger. Price $1 00. For sale by D. Van Nostrand.

This little book presents a new graphical method for analyzing the action of slide-valves designed to simplify the solution of all such problems. The illustrations are abundant, eighty in number, and are otherwise sufficient for the purpose.

The three parts to the work treat respectively of the Slide-Valve, Link Motions and Cut-Off Gearing.

Many students who fail in obtaining needed instruction from more elaborate treatises will doubtless find their wants abundantly satisfied by this compact little work.

Manual of Introductory Chemical Practice. By Geo. C. Caldwell, S.B., Ph.D. and Abram A. Breneman, S.B., of Cornell University. Second Edition revised. New York: D. Van Nostrand. Price $1.50.

This manual was originally designed as a guide for students beginning laboratory work. The result of two years' trial justifies a new edition of the work, and also the expectation that it will be acceptable to teachers who wish to illustrate a short course in chemistry.

The plan is chiefly to illustrate the character of chemical changes as the following extract from the contents will show: Introductory; Fusion-Vaporization; Solution Crystalization; Conditions affecting Reactions; Properties of the Elements; Compounds; Combining Proportions; Oxidation; Flame Reduction; Grouping of Elements; Binary and Ternary Compounds; Betholiet's Laws; Decomposition; Surface Action; Quantitative Analysis.

A complete list of apparatus needed is given, with copious illustrations. This is a book that has been long needed by teachers of Elementary Chemistry.

RAILROADS—THEIR ORIGIN AND PROBLEMS. By CHARLES FRANCIS ADAMS, Jr. New York: G. P. Putnam's Sons. Price $1.25. For sale by D. Van Nostrand.

These two essays will be widely read on both sides of the Atlantic. As Railroad Commissioner of Massachusetts, the writer has of late years given annually such evidence of his ability to deal with this great problem as to gain respectful attention to his views in many countries.

The second essay, the Railroad Problem, as it is presented to all countries is of the most general interest.

The masterly character of the author's previous writings in this field is evident in this essay.

CHEMICAL EXPERIMENTATION. By SAMUEL P. SADTLER, A.M., Ph.D. Louisville: John P. Morton & Co. Price $2.50. For sale by D. Van Nostrand.

This is an excellent guide to either laboratory or lecture-room work, and will prove serviceable for either teachers or pupils.

The series of suggested experiments includes all the non-metals and thirty of the metals. The illustrations are numerous and of the most excellent character. The directions for the preparation are exceptionally clear.

An appendix gives specific instructions about the common manipulations of the laboratory such as cutting and bending glass, blowing bulbs, fitting up corks, etc., etc.

Some useful tables, comparing the different scales, are also added.

ANNUAL REPORT OF THE CHIEF SIGNAL OFFICE TO THE SECRETARY OF WAR FOR 1877. Washington: Government Printing Office.

The present report is in no particular behind its predecessors. Some new features in charting observations are noticeable, and the general excellence of the maps is in every way gratifying.

There is an evident determination in the department to maintain the position now held—that of first in the world in all that pertains to observing phenomena, and freely disseminating such knowledge as is obtained from the information received.

Ninety-five stations make tri-daily telegraphic reports, thirty-two make one telegraphic daily report only, and one station only sends two reports; a total of 128 stations reporting by telegraph.

Some reduction of the force was made by Act of Congress, July, 1876, which it is hoped will be but temporary. A brief examination of the results of the last two or three years will lead to the conviction that true economy lies on the side of an extension of the system of observations under the superior management that now directs it.

A TREATISE ON FILES AND RASPS. By Nicholson File Company, Providence.

This is a beautifully illustrated thin quarto, treating briefly of the method of file manufacture and, with great fullness, of the varieties of files and rasps manufactured by this enterprising company.

VAN NOSTRAND'S SCIENCE SERIES, No. 38.

MAXIMUM STRESSES IN FRAMED BRIDGES. By Prof. WM. CAIN, A.M., C.E. New York: D. Van Nostrand. Price 50 cts.

This number discusses the Howe, Pratt, Triangular, Whipple, Fink, Bow String and Schwedler Bridges, for the maximum strains caused by two locomotives and a train of cars—the usual loads assumed in practice. A comparison is also made of the respective weights of these trusses as computed from the strains. The unit strains used in finding these weights are obtained from a modification of Launhardt's formula, which is based upon the well-known Wöhler's law.

The new features in this book are the analytical treatment of the subject of maximum chord strains due to the loads assumed, the ascertaining the most economical depth of trusses, besides other points.

The discussion of the Schwedler bridge—which is so earnestly recommended by its author—will probably be of interest to engineers who have not studied this system.

The treatise is complete in itself; the full analysis for each truss being given; and it is hoped that the compact form in which the subject matter is presented—stripped of unnecessary matter—may prove an agreeable feature to engineers.

MANUAL OF THE VERTEBRATES OF THE NORTHERN UNITED STATES. Second Edition. By DAVID STARR JORDAN, Ph.D. Chicago: Jansen, McClurg & Co. Price $2.50. For sale by D. Van Nostrand.

This is for the use of students of zoology to aid in identifying the species of the vertebrates of our own country.

The author has studied briefly and has got, we presume, a complete manual within a convenient-sized volume, useful to collectors all over the country.

THE LIFE OF JOHN FITCH. By THOMPSON WESTCOTT. Philadelphia: J. B. Lippincott & Co. Price $1.50. For sale by D. Van Nostrand.

A new edition of this biography of the inventor of the steamboat is noteworthy. It is in good style, and as it is a record of an important era in steam engineering in this country, it is worthy of a place in every library.

MANUAL FOR MEDICAL OFFICERS OF HEALTH. By EDWARD SMITH, M. D., F.R.S. Second edition. London: Knight & Co. Price $3.50. For sale by D. Van Nostrand.

The duty of the health officer in this country is in general not very well defined; the functions of such an officer are, as recent experiences have taught us, but illy understood. But, as in our present condition which promises improvement, we have followed the lead of older countries, it is reasonable to infer that from Dr. Smith's writings much may be gleaned which will prove valuable in the future.

Although written for use in England, a very considerable portion of the work will be found valuable here.

L'Annee Scientifique et Industrielle. Par Louis Figuier. Paris: Libraire Hachetti. Price $1.40. For sale by D. Van Nostrand.

This Scientific Annual chronicles the advance during 1877 in the several departments of Astronomy, Meteorology, Physics, Mechanics, Chemistry, Building Construction, Biology, Hygiene, Medicine and Industrial Arts.

The selection of articles and their arrangement for this Annual are good. The only illustrations are of the Bell Telephone.

Handbook of Inspectors of Nuisances. By Edward Smith, M. D., F.R.S. London: Knight & Co. Price $2.00. For sale by D. Van Nostrand.

This work is of more use in Great Britain than in this country, being adapted to the laws of that country. It is to be hoped, however, that it will serve as a guide in shaping our laws so as to insure a better condition of sanitary regulation in the future.

The methods of conducting examination of sewers and of disinfecting filthy localities are such as may be profitably followed in any civilized community.

Food from the Far West, or American Agriculture. By James Macdonald. New York: Orange, Judd & Co. Price $1.50. For sale by D. Van Nostrand.

This is made up from a series of letters to the *Scotsnan,* which the author was commissioned to write to that paper, in order to inform its readers on the subject of the importation of dead meat from the Western States. Four chapters have been added to the above to complete the book. One of these presents statistics, two are devoted to American Short-Horn Breeding, and one is on what science says to the cattle feeder.

As a summary of the meat producing resources of our Great West, the work is doubtless accurate, and is certainly interesting.

Sanitary Engineering. A Guide to the Construction of Works of Sewerage and House Drainage. By Baldwin Latham, F.G.S., C.E. Second Edition. London: E. & F. N. Spon. Price $12.00. For sale by D. Van Nostrand.

The first edition of this book was speedily exhausted. The demand was still so great that an American reprint was issued in parts. It gave an impetus to Sanitary Engineering in this country which was much needed.

The second edition is much larger than the first, the additional matter relating chiefly to improved methods of Sewerage.

The work still holds the first place as a compendium of Sanitary Engineering practice.

Electric Lighting. A Practical Treatise. By Hippolyte Fontaine. Translated by Pajet Higgs, LL.D. London: E. & F. N. Spon. Price $3.00. For sale by D. Van Nostrand.

This work describes chiefly the Gramme Machine and the different forms of lighting apparatus which have been tried in connection with it.

The subject is one of great interest, as the time of lighting public squares, railroad stations, and public halls, by the electric light, seems certainly at hand, and, although we have not passed the experimental stage, the French engineers have accomplished so large a measure of success that we are at present content to accept the methods they recommend. The summary of their processes is presented by M. Fontaine.

Oeuvres Completes de Laplace. New Edition. To be completed in seven volumes 4to Paris: Gauthier-Villars. Price, per vol. $8.00. For sale by D. Van Nostrand.

The works of Laplace still hold their high position in the estimation of students of mathematical science. To read the Mecanique Celeste understandingly is to earn the respect of mathematicians; to omit such a labor in a course of mathematical study is to create the suspicion in the minds of scholars that the claims of such student to a fair order of mathematical talent are, at best, pretentious.

There seems to be now no promise of a time when these works will be held in less esteem. Although other processes of investigation may supersede those of Laplace, yet the accomplishments of this great astronomer are so identified with the material progress of science, that his name is as familiar as Newton's, and libraries in any country are incomplete without his writings.

Institution of Civil Engineers.—Through the kindness of Mr. James Forrest we have received the following publications of the Excerpt Minutes of the Proceedings of the Institution of Civil Engineers:

The Centrifugal Pump, by Wm. Cawthorne Unwin, M.I.C.E.

The Flow of Water through Level Canals, by James Atkinson Longridge, M.I.C.E.

On the Ventilation of the Mont Cenis Tunnel, by William Pole, F.R.SS.

The Strength of Flat Plates and Segmental Ends, by Daniel Kinnear Clark, M.I.C.E.

The Main Drainage of Paris, by Felix Target, A.I.C.E.

The Huelva Pier of the Rio Tinto Railway, by Thomas Gibson, A.I.C.E.

Chemical and Physical Analyses of Phosphorus Steel, by Alexander Lyman Holley, M.I.C.E.

Railway Appliances at the Philadelphia Exhibition, by Douglas Galton, F.R.S., A.I.C.E.

MISCELLANEOUS.

Rensselaer Polytechnic Institute.—The Alumni of this celebrated Institute, regardful as they have ever been of sustaining its fame, will be gratified to learn of the appointment of David M. Greene, C. E., as the Director.

Professor Greene graduated at the Institute with the class of 1851, and subsequently occupied the chair of Professor of Geodesy. He was for a time also the Professor of Engineering in the U. S. Naval Academy.

For the past few years he has been busily engaged with his professional labors. He has worn a high rank among American Engineers, and his recent appointment will be especially gratifying to his confreres of the American Society of Engineers.

#VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

NO. CXIX.—NOVEMBER, 1878.—VOL. XIX.

ON THE PROPOSED REMOVAL OF SMITH'S ISLAND.

By Prof. LEWIS M. HAUPT.

Read before the Engineers' Club of Philadelphia.

The commercial interests of Philadelphia have developed to such an extent as to create a demand for greater wharfage facilities with deeper water; and that cereals and merchandise may be delivered without too many handlings it is advisable that cars should be run immediately alongside the vessels to be laden. To accomplish this it is proposed to lay tracks on Delaware Avenue, already too narrow, and to make provision for the space thus occupied by extending the Port Warden's line farther out and thus contract the river channel now only about 800 feet wide at the narrowest part. Several of our largest shippers have requested permission to extend their wharves several hundred feet. Were this to be allowed in a few isolated cases it would introduce dangerous barriers to navigation, and if an advance be made all along the line it would seriously contract the channel, unless a portion of Smith's Island can be removed.

The project is by no means a physical impossibility, as much larger deposits have been successfully taken away. The work of improving the river Neva in Russia is one of far greater magnitude as the following clipping from the *Ledger* witnesseth:

"Following the large order from Russia for Philadelphia locomotives comes the information that the Russian Government has just concluded, through Major W. R. Bergholz, a contract with the Morris & Cummings Dredging Company of New York, for deepening to a uniform depth of twenty feet the channel of the river Neva, between Cronstadt and St. Petersburg. Twenty-five thousand dollars were cabled to Russia last week as earnest money. The dredging 'plant' will cost $200,000. Most of it will be constructed in this country, and will be on hand ready for operation on first of May next. The quantity of mud, etc., to be excavated is estimated at 15,000,000 cubic yards, and the work must be completed in four years. (The contract was obtained after sharp competition with English operators.)"

To widen the Ship Channel of the Delaware River 1000 feet along the Smith's Island front, and to a depth of 18 feet, would require the removal of only about 5,000,000 cubic yards of material at a cost of about $1,000,000.

The same width and depth of channel may be obtained if desired, for less than $\frac{1}{10}$ the cost of dredging, by a careful adjustment of the *regimen* of the river by auxiliary constructions such as jetties, rip-raps, sand fences or bottom-dams. Before these structures can be located precisely, it will be necessary to make a

careful examination or survey of the river to determine its surface and mean velocity, the nature of its bed, its cross section, the directions of its banks and currents, whether straight or sinuous and its longitudinal slope. These quantities are evidently functions of each other, and together constitute what is known as the *regimen* of the river. So mutually dependent are they that a change in any one will affect them all.

The tendency of rivers is to maintain a constant *regimen*, and this fact is the key to the solution of many problems relating to river improvements.

All fresh water flowing through alluvial deposits carries with it in suspension more or less earthy matter. We find, therefore, a continual tendency to deposit where the velocity is least, and to scour where it is greatest, and this mechanical action of water is constantly pushing the river bed downwards to the sea. It is estimated that the "Mississippi annually transports to the Gulf a volume of alluvion one mile square and 241 feet high, weighing over 400,000,000 tons, and at the same time it pushes over the bar at its mouth an amount equal to $\frac{1}{10}$ of that sum," making altogether over 272,000,000 cubic yards. This is far beyond the limits of our present mechanical possibilities. Thus the river furnishes its own motive power, gathering up its load as it rolls along, and dumping it at the end of its course, not always, it is true, just where it is desired, unless the spot be indicated by depositing some obstruction, in which case it will not fail to notice the sign "dirt wanted here," and continue adding until its *regimen* is re-established, when it will move on as before.

Let us assume a straight length of river-bed of uniform cross section, a certain fixed stage of water and inclination, direction and nature of bed, and we will find the discharge will be constant, or the water and its suspended earthy particles will move on with a uniform velocity, some being deposited, it is true, while others are pushed along or gathered up; but the mean velocity of the parabola representing the wave front will remain uniform. So soon, however, as the above relations are disturbed, the effect becomes at once manifest. Suppose, for example, the cross section be increased; the velocity would be reduced, and, consequently, the carrying and scouring capacity being limited, deposits would be formed; or if a bend be introduced, it would retard the threads of the current on its side of the stream, whilst those of the opposite side, flowing faster, must return to fill the vacuum which would otherwise be created, and thus be drawn over towards the bend to receive a new impulse from the inner threads, and by these constantly recurring differences of velocities cause the alluvium to be precipitated.

Again, should one stream intercept another of lesser volume, the mouth of the latter would become choked up with a bar, in consequence of the reduced velocity of its currents, which will then spread out laterally in the effort to maintain a constant discharge, and so form deltas. For this reason, I do not believe the improvement at the South West Pass to be a permanent one. The effect will ultimately be to elongate the bar into the deeper water of the Gulf, but the extension will be so gradual that the expense of maintaining an open channel will be very slight.

On the other hand, anything tending to reduce the cross section and so increase the velocity or discharge will produce a scour, and unless the bed be of rock or hard pan, will deepen or widen the channel. Such contraction may be accomplished in two ways, either laterally by drawing in one or both banks, or vertically by filling up the bottom to a limited height.

As a consequence of the principles just enunciated we will find in an alluvial bed that where the distance between the banks is least the channel is deepest; where greatest it is shallowest, or bars are most numerous; where points jut out, forming elbows, there will invariably be a shoal on the lower convex shore, whilst on the opposite or concave side will be found the best channel; that at the efflux of a lake, or broad expanse of river, where the several currents assemble before a final shoot through the contracted water-way, there will be deposits, and that at the mouths of rivers emptying into running water or beaches exposed to the winds and waves, bars will be formed, sometimes to such an extent as entirely to interrupt navigation.

Indeed, on the south shore of Lake Superior I have walked over the mouths

of some small streams without suspecting their presence, and only discovered them by exploring inward.

With a knowledge of these principles it is possible to predict with almost absolute certainty just where shoals may be found by a mere inspection of the outlines of the stream.

The tendency of an elbow to cause deposits is one which constantly increases, so that the bar creeps up stream to meet the elbow and ultimately joins itself to it, forming a spit. This so greatly reduces the water-way as to cause erosions at other points that the regimen may be preserved and thus new channels are cut through. Hence the fickleness of rivers with low, earthy banks.

But to return to the application:

Smith's, or more more properly Windmill, Island is represented, so far back as we have any authentic data, considerably farther down the river than at present, and it has been gradually creeping up stream, until now its upper end is about opposite Chestnut Street. To corroborate the above theory I have examined the oldest obtainable maps in the Mercantile Library, Pennsylvania Historical Society, Philadelphia Library, City Engineer's Office, and Franklin Institute, with the following results:

The map of Thos. Holme, Surveyor General of the Province, 1681, shows a small island opposite Spruce Street, and another much larger about opposite Kaighn's Point.

In 1762 Windmill Island extended from below Christian to below Spruce Street, with bars all the way up to Cooper's Point. (No name to map.)

The map of Scull & Heap, 1777, gives about the same position for the island.

On the map of 1796 the island extends from below Shippen (now Bainbridge) Street to below Chestnut, with a shallow channel across it opposite Spruce Street; or, in other words, a shoal showing above water between Spruce and Chestnut Streets, but not yet joined to the body of the island.

Hill's map, 1808, represents six small islands or flats dry at low water extending from Christian to Vine.

In 1811, the island extended from between Shippen to between Market or High Street, with bars at each end, the upper one being attached to the island, the lower reaching to Washington Ave.

The map of a survey by Jno. A. Paxton, and drawn by Wm. Strickland, Engineer (1824), shows three islands extending from Catherine to Arch Streets with shoals at either end.

Port Warden's map (1836) having no date other than that of its presentation to the Franklin Institute, and no name, shows the upper end of island reaching above Chestnut Street with isolated upper bar extending to Arch Street. The lower limit is not defined. (No canal shown.)

On the map of F. I. Roberts (1838) the island extends from Shippen to above Chestnut Street with a separate shoal reaching as far as Arch Street, and a shoal below from Washington Avenue to above Christian. (Canal shown as cut through.)

Map of Chas. Ellet, Jr. (1839); island from South to between Market Street (with canal) and isolated bars above and below, the latter reaching from below Washington Avenue to Fitzwater Street, the former to Cherry Street. Total length with bars, $1\frac{3}{5}$ miles.

The U. S. Coast Survey map (1843) shows the island as extending from Shippen to between Market, with ferry canal cut through, also a detached bar below, dry at low tide; one fathom depth just above Washington Avenue, and an *attached* bar on the up-stream end extending to Cherry Street, with one fathom of water below Callowhill Street.

The Surveys of Richard Hexamer (1868) limit the island by the prolongation of South and Chestnut Streets; and Dyer's map of 1869 makes it reach from Shippen nearly to Arch Street.

Of all these the only maps giving any information concerning the depths are those of the U. S. C. S., made in 1843—and the Port Warden's map having no date affixed—and, consequently, the only one upon which any reliance can be placed is that of 1843. Still a general comparison of all shows an average movement of the lower end of the island up stream from Christian to South Street, a distance of 1900 feet in 106 years, or from 1762 to 1868.

From the comparative soundings of 1819 and 1836 as given on the Port Warden's Map and those of the Coast

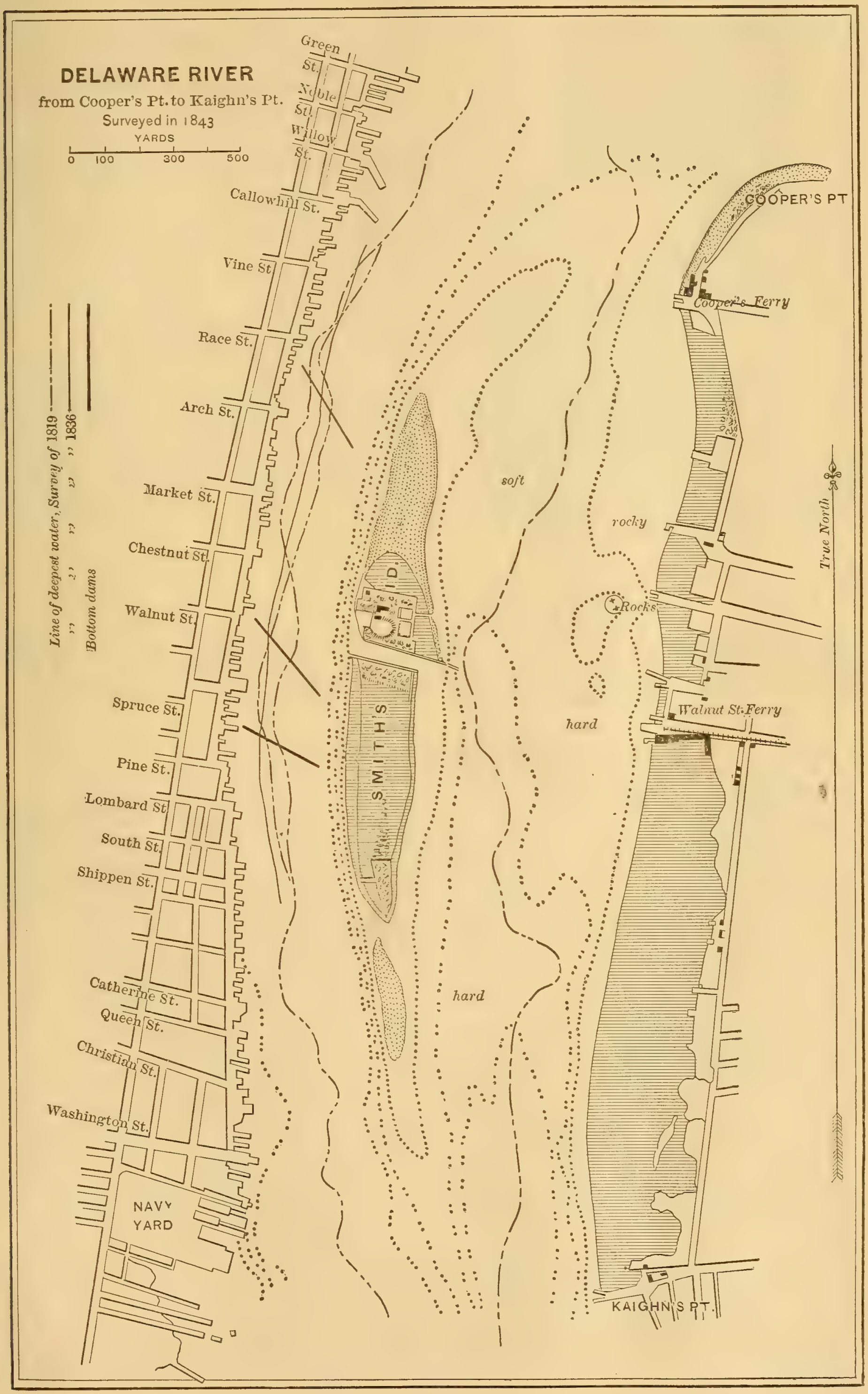
Survey of 1843, we are enabled to trace in *plan* the axes of the deepest water at those dates with the following notable results. In 1819 the axis was 250 to 300 feet from the Port Wardens line and very nearly parallel thereto. In 1836, after 17 years, it had evidently moved slightly towards the City shore, and in 1843 was still nearer from Race Street to Chestnut Street, approaching to within 90 feet of the pier heads at Market Street. At Chestnut Street it made a bend, convex towards Smith's Island, having its maximum ordinate opposite Walnut Street, and remained outside the lines previously occupied to beyond the limits of the maps.

Theory would suggest that as the approach to the island happened just opposite the canal cut for the Philadelphia and Camden Ferry Company, it must have resulted from the set of the current in that direction, and as there is a corresponding flexure of the deepest water line in the Jersey channel it corroborates the theory.

A search for the date of the opening of the canal resulted in a note from Mr. Thompson Wescott to the effect that "the work was authorized by Act of Council, Feb. 14, 1838, and damages assessed the same year @ $2000. The Canal, 150 feet wide, was cut soon afterwards," he supposes in 1838–9. At first, both sides of the canal were of the same length, in consequence of which it filled up rapidly, but by extending the upper side into the Jersey channel to intercept the flood tide and the lower side into the Pennsylvania channel, to catch the ebb, and cause a scour, it has since been kept open. The survey of 1843, four years after the opening of the canal, shows a very marked effect upon the axes of the currents. An examination of the *profile* shows 29 feet opposite the old Navy Yard, near the lower end of Shoal, below the island. Thence the depth increases with undulations to 58 feet at a point above Race Street, at the upper end of the shoal above the island (distance 6800 feet), whence it suddenly shoals to 31½ feet opposite Cooper's Point (distance 3200 feet), at which place the river is widest.

It deepens again to 37 ft. opposite lower end of Petty's Island, and shoals gradually to a point above the Reading Company's wharves where there are but 19 feet of water, thence the depth increases to 26 feet at head of island, and, finally, runs up to only 13 feet, just below Fisher's point, where it pitches down suddenly to 38 feet.

Returning by the Jersey channel we find the distance somewhat greater, by the deep water line, because it is more sinuous in consequence of the greater width of channel and less depth of water. The same general observations obtain in this case as in the other, *i. e.*, where the river is broadest it is shallowest and *vice versa.* Considering the profiles of the two channels together, we find, as a rule, the average depth greatest where the breadth is least, and the reverse, so that we may safely conclude from these (observations and deductions) that if by any means the breadth or depth be reduced the depth or breadth will be increased in consequence of the scour produced by the increased velocity given to the stream. This diminution of the sectional area may be produced either laterally by constructing jetties and levees, or vertically by forming subaqueous dykes or dams on the bed of the stream, and crossing the same either directly or obliquely. The latter being generally better as it will change the direction of the resultant thread of the current so as to cause it to act more powerfully on the deposits to be removed. In applying these principles to the case in point, I should recommend the latter method of reducing the water-way by oblique dams (see map) constructed, first of large stone thrown into the river on range lines established by signals erected on the island, and filling in on the up-stream side with rip-rap or ballast from vessels. The Penna. end of the dam should be somewhat higher than that resting on the island, and no part of it should have less than thirty feet of water over it at mean low tide. As an auxiliary structure I should extend the pier heads near Willow Street (see map) down stream, at such an angle as to deflect the current towards the head of the island, and believe, that by thus expending a few thousand dollars, the present channel may be so deepened and widened, as to avoid entirely the *removal* of the island. At present I do not think it advisable to remove any of the fast land


DELAWARE RIVER
from Cooper's Pt. to Kaighn's Pt.
Surveyed in 1843
YARDS
0 100 300 500
Line of deepest water, Survey of 1819
" " " " 1836
Bottom dams
Green St.
Noble St.
Willow St.
Callowhill St.
Vine St.
Race St.
Arch St.
Market St.
Chestnut St.
Walnut St.
Spruce St.
Pine St.
Lombard St.
South St.
Shippen St.
Catherine St.
Queen St.
Christian St.
Washington St.
NAVY YARD
SMITH'S ID.
soft
rocky
Rocks
hard
hard
COOPER'S PT
Cooper's Ferry
Walnut St. Ferry
KAIGHN'S PT.
True North

which is now sufficiently protected by a casing of piles; but, on the contrary, I believe it would work serious injury to the harbor were any very considerable part of the island to be removed, as in that case the deep water channel would recede from the Penna. shore where bars would soon form and destroy the approach to the harbor. It is also serviceable as a breakwater, besides furnishing so much more room for stowage and wharfage which are as essential to commercial interests as good water.

I do not believe the time has yet arrived when it will pay to pull up the piles now surrounding the island, and set them further back, but I do think it would be expedient to deepen the channel close up to the present wharf lines on the island by the inexpensive method proposed.

The question will naturally arise as to the effect upon the lower reaches of the river from the alluvium thus disturbed. It is my opinion that it will not seriously affect the present navigable channel, but it will doubtless add to the magnitude of the bars already existing below Greenwich, Gloucester and Red Bank.

As to the time required to effect these changes it is impossible to make any predictions with certainty, for it will depend largely upon the stages of water, and be retarded to a considerable extent by the flood and stand of the tide, but it will doubtless improve the channel, at least as rapidly as the demand for greater shipping facilities increases.

A new survey of the river is now being made by the U. S. C. S., under the supervision of Capt. S. C. McCorkle, the results of which will be looked for with great interest, as indicating more correctly than can be done by other means the exact location of any proposed improvement.

WATER SUPPLY TO A STAMP MILL IN VENEZUELA, WITH NOTES ON KUTTER'S FORMULA.

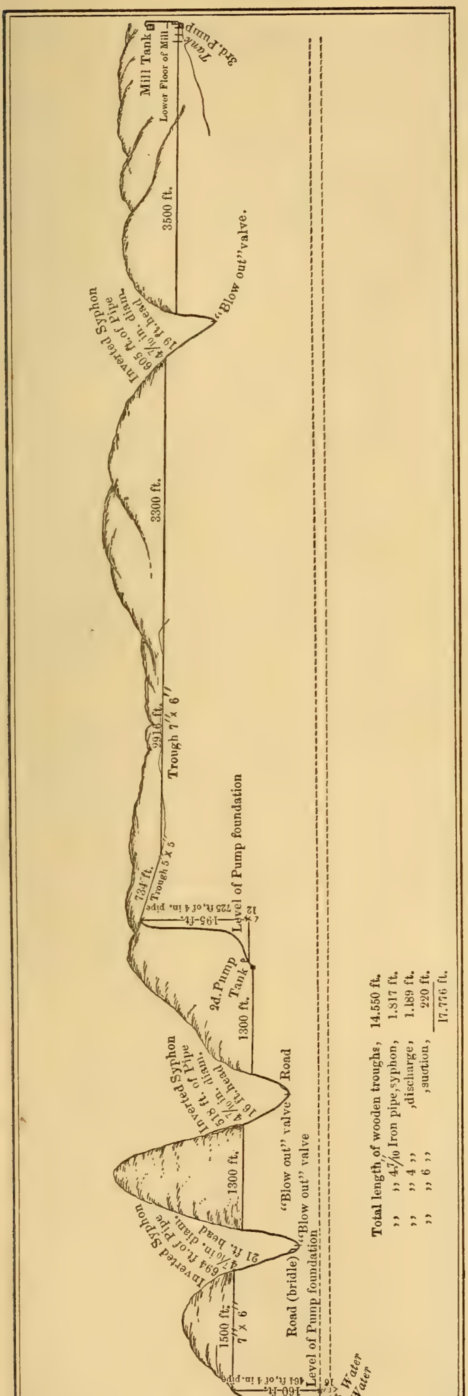
By WM. A. BIDDLE.

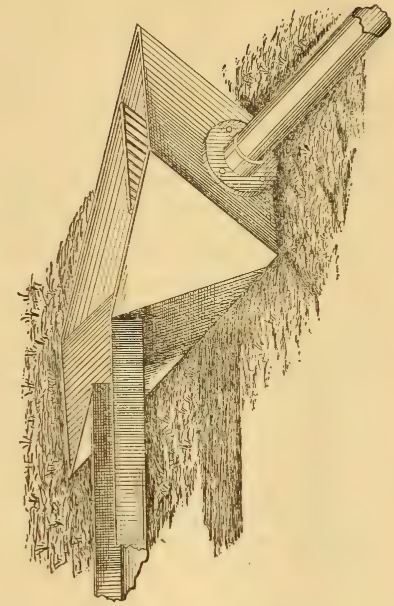
From a Paper read before the Engineers' Club of Philadelphia.

In making the necessary calculations for the location and construction of works to supply water to a quartz mill in the gold region of Venezuela, South America, the wide differences between the formulas given by well-known authorities for the flow of water in pipes and open channels became very apparent, particularly when applied to comparatively small dimensions. This mill of thirty stamps and the general plant of the company owning it, had previously been built close by the outcrop of the quartz vein and almost three miles from the nearest stream, in the disappointed expectation, on the part of the gentlemen then managing, of getting a supply of water by sinking to a moderate depth on the vein.

In order to show the conditions to which the formulas were applied, and also as illustrating some of the peculiarities met with in that country, a few descriptive notes are given of the works referred to.

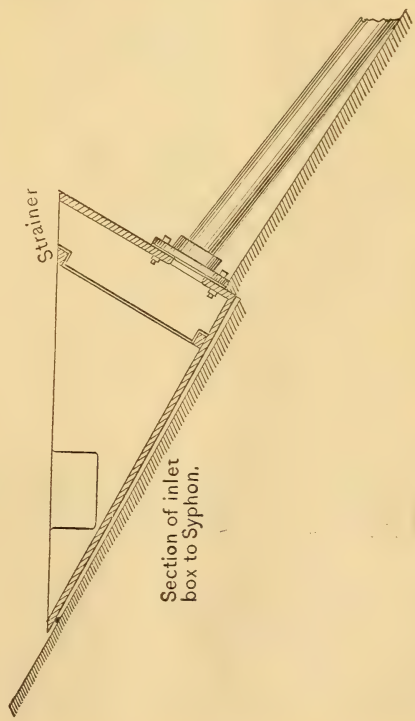
These consisted (see Profile) of a pumping station at the foot of a steep hill on the Yuruari River (an affluent of the Essequibo), delivering water 160 feet above the pump into a line of troughs (7×6 inches inside, made of inch boards) laid along the hill sides on a descending grade of .3 per 100 for a length of 4,100 feet, the line crossing two deep ravines by inverted syphons (of boiler flues five inches diameter outside) 694 feet and 518 feet long, bringing the water to the second pumping station at the foot of a range of hills extending inland, whence the water was delivered 195 feet above the pump into a second line of troughs 10,450 feet in length—this line crossing another ravine by an inverted syphon 605 feet long—bringing the water into a ravine immediately below the stamp mill, whence a third pump run from the mill boilers delivered it into the mill tank; the total surface length of the line, including the section and discharge pipes of the pumps, being 17,300 feet, and the





total height gained from the river to the mill tank being 310 feet.

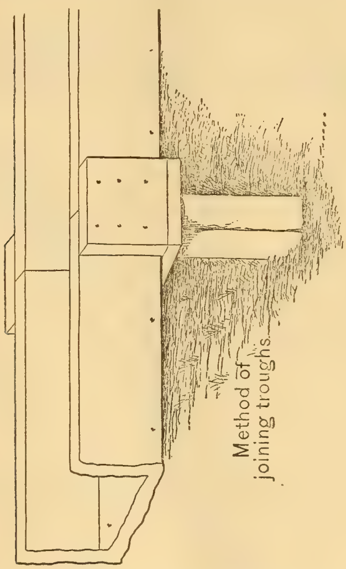
The pumps at the two stations were Worthington's Duplex, 16-inch steam cylinders, 8-inch plungers, and 10-inch



Section of inlet box to Syphon.

stroke, with 6-inch suction and 4-inch discharge pipes. The boilers were of locomotive pattern, having forty-five 3-inch flues eight feet long, and the exhaust of each pump was led into the smoke stack of its boiler. Check valves were placed in the discharge pipes close to the pumps, and inch pipes were tapped in just above the valves and leading to the boilers, which were thus fed by the pressure of the water column, though having injectors for use in case of necessity.

The boards for the troughs were sawed at the company's sawmill, close by the stamp mill. The durable native woods, with one or two exceptions which are of very rare occurrence, are extremely hard and heavy. The boards come from the saw quite smooth, but it is almost impossible to drive a nail near the edge without splitting the wood, and, therefore, the side boards of the troughs were bored for the nails by a machine fitted up for the purpose in the saw mill.



The troughs varied in length from twelve to sixteen feet, and were so stiff and strong that no supports were needed between the joints.

The pumps, boilers and fixtures, pipes, pipe fittings and tools, valves, bends, bolts and nuts, nails, indeed everything used in and on the work except the boards, had to be shipped by sailing vessels from New York up the Orinoco River some 300 miles, landed by lighters, loaded on ox-carts, and hauled 150 miles inland to the mines. Fortunately both pumping stations were close to the cart roads, but many of the syphon pipes had to reach their destination among the hills by being packed on donkeys.

The preliminary grade line for the troughs was run with a builder's level, or triangle, eight feet long and made of boards. This was really the quickest and handiest instrument that could be used, for almost every foot of the distance had to be cut through the dense tangle of vines, briers and lianas which form the undergrowth of the tropical forests, and the amount of chopping was thus reduced to an opening just sufficient to drag the triangle along, while by driving pegs and keeping "tally" both the measurement and the grade line were obtained in the one operation with enough precision for preliminary work. The final leveling, after the line had been approximately located and cleared, was done with a "Heller & Brightly" small mining level, which proved a most satisfactory instrument.

In calculating the heads to be given to the inverted syphons for a maximum discharge of thirty-five cubic feet per minute, two formulas were applied, Weisbach's for friction head (velocity head to be added), and Eytelwein's as given by Trautwine for total head, and also by Beardmore; with the following results:

	Feet long.	Eytelwein.	Weisbach.	Diff.
1st. Syphon,	694	19.09	14.67	4.42
3d. "	605	16.71	12.83	3.88
2d. "	518	14.39	11.04	3.35
				11.65

Those by Eytelwein being thirty per cent. greater than those by Weisbach. In the absence of any record of the use of such small pipes (4.7 inches inside) as inverted syphons, it was thought wiser to take the larger results though involving a greater loss of elevation by almost twelve feet, and also to add two feet for bends and possible obstructions in the pipes, so that the heads actually given for the above lengths were twenty-one feet, nineteen feet, and sixteen and a half feet respectively. Trautwine remarks on this subject as follows:

"Recent experimenters state that the old formulae in use, though generally

sufficiently exact for ordinary practice, are to some extent defective. Weisbach asserts that for velocities less than $1\frac{1}{2}$ feet per second (full one mile per hour) the heads given by the other formulae are too small; and for higher velocities too great. On the other hand many measurements by competent engineers seem to show that the old formulae give all the accuracy required in common practice."

The first trial of the works, and unfortunately the only one made before the engineer left the country, included only the first pumping station, 1,500 feet of troughs and the first syphon, and was made under circumstances which rendered it impossible to test the performance of the syphon further than ascertaining that the 22 cubic feet per minute, then estimated to be flowing through the troughs, passed the syphon with no indication of filling the high side. The three syphons have now been in use nearly two years, but the only information yet received about them states, that when the works are furnishing more water than the mill needs the syphons show no sign of filling the high sides. This proves that the formula used was certainly *safe* in this case, but it is hoped that further details will soon be received by which to learn how much it is in *excess* of safety, and whether Weisbach's formula *might* have been safely used, since an unnecessary loss of twelve feet of elevation could hardly be considered by Mr. Trautwine as "sufficiently exact for common practice," and sometimes might be of very serious importance.

At the trial, during which the pump was run slowly, the water flowed in the troughs three inches deep, and a small piece of inch board floated through the 1500 feet in $9\frac{1}{4}$ minutes, or at the rate of 2.7 feet per second. If this was the true surface velocity, then taking the ratio between the surface and mean velocities at .85, the mean velocity would have been 2.3 feet per second, giving a discharge of twenty cubic feet per minute. But the float was of such heavy wood that it was immersed its entire thickness, thus having its under side only two inches from the bottom of the trough, and there can be no doubt that if a strictly *surface float*, such as a thin disc of light wood, had been used, a considerably greater velocity would have been shown. Moreover the line of troughs in following the grade along the contour of the hillsides had almost constant changes of direction at the joints, while the formulas for discharge through open channels are given for *straight* channels, so that in order to compare them closely with the observed result in this case a correction should be applied to the result both for thickness of the float and for crookedness of the channel.

The differences between the formulas, both older and more recent, that were tried on this case, are in the values given to the co-efficient C in the formula for mean velocity, in feet per second,

$$V=C\sqrt{RS}$$

in which R is the hydraulic mean radius (area of water section divided by its wet perimeter), and S is the fall in one unit of length. Here the water section was 7×3 inches, or $.58\times.25$ feet$=.145$; and $R=\frac{.145}{.25+.58+.25}=.134$. The fall being .3 per 100,

$$S=.003,\text{ and }\sqrt{RS}=\sqrt{.134\times.003}=.02$$

Beardmore gives for ordinary use,

$$V=94.2\sqrt{RS}$$

And for "channels constructed with great care and straight in direction,"

$$V=100\sqrt{RS}$$

The former gives in this case a mean velocity of 1.88 feet per second, and the latter two feet, corresponding at 85 per cent. to surface velocities of 2 2 and 2.35 feet per second respectively—both much below the observed result even without correction.

Weisbach gives 92.5 as the co-efficient of $\sqrt{RS}$, and other authorities vary from 68 to 100.

Bazin gives four different co-efficients for different degrees of smoothness in the material of the channel, all including the hydraulic mean radius as a factor, and the greatest being, for smooth plank (Higham's tables),

$$V=\frac{1}{\sqrt{.0000457\left(\frac{R+.098}{R}\right)}}\sqrt{RS}$$

This, applied to the case in question,

gives a co-efficient of 112.36, and a mean velocity of 2.25 feet per second, corresponding at 85 per cent. to a surface velocity of 2.64 feet per second—still below the observed result even without correction.

Kutter's co-efficient includes as factors both the hydraulic mean radius and the inclination, and also a "natural constant" depending on the material, and for which a table of values is given, varying from .009 for smooth plank to .035 for rivers and canals full of weeds and stones. The formula is thus (Higham's tables)

$$V=\frac{\left(41.6+\frac{1.811}{N}+\frac{.00281}{S}\right)\sqrt{R}}{\sqrt{R}+N\left(41.6+\frac{.00281}{S}\right)}\sqrt{RS}$$

Taking the value of N for smooth plank = .009, this gives for the case in question a co-efficient of 119.145, and a mean velocity of 2.383 feet per second, corresponding at 85 per cent. to a surface velocity of 2.8 feet per second, which may be considered as agreeing closely with the observed result of 2.7 feet per second corrected for thickness of the float. But as this result was obtained in a channel very far from straight it would seem that even Kutter's co-efficient is slightly below the truth for this case. It is, however, very close, and much nearer than that of Bazin, which has been thought accurate when applied to small channels, though acknowledged to fail on large rivers.

According to Kutter's formula a depth of .4 feet (say 4⅘ inches) of water in the troughs would have a mean velocity of 2.82 feet per second, which would give the maximum discharge of 35 cubic feet per minute, assumed in calculations for the line, with a surplus velocity of 3.32 feet per second.

The English translation of Kutter's work (by L. D. A. Jackson, A.I.C.E.) gives an interesting account of his investigations, in which a great number of recorded observations, as well as his own, were tabulated and compared in various ways and with most laborious research. Without going fully into the mathematical details, it describes the *method* of deriving the new co-efficient, which may be said to consist largely of a synthetic application of analytical geometry, by plotting the observed co-efficients as ordinates, to abscissas representing values of R, and to others representing values of S.

It is claimed that this new formula gives co-efficients of $\sqrt{RS}$ which will be found correct whether applied to a petty drain or an immense river. The formula of Humphreys and Abbot for *large* rivers had been accepted as the best yet proposed, but their modification of it for *small* streams, when applied to small channels with considerable inclinations, is said to fail as completely as that of Bazin on large rivers. But Kutter's formula is said to have been proved on the great depths and low inclinations of the Mississippi, and to have given co-efficients equal to those found there by Humphreys & Abbot's observations, which have gone as high 254.4. This and its close agreement with observed results in the case of the small trough which has been described, certainly seem to justify the claim made for it and entitle it to the confidence of engineers.

Kutter's investigations have demonstrated the following important and interesting facts: that for a constant value of N, when the hydraulic mean depth (R) is one metre, the co-efficient is practically the same at all inclinations; that with values of R *greater* than one meter, the *co-efficient increases* as the *inclination decreases*, an extreme case of this being the very high co-efficients for the Mississippi; while with R *less* than one meter, the co-efficient increases as the inclination increases up to S=.001, beyond which point any further increase of inclination has practically no effect on the coefficient, which then varies only with R.

In the preface to the English edition of Kutter, the translator alludes to the anomalous fact that "the English-speaking races," while taking the lead in engineering progress in other directions, have been very far behind in hydraulics, one evidence and consequence being that this book which appeared in Austria, Germany, and Switzerland, in 1870, and was *immediately* translated into French, Dutch and Italian, was not published in England until *six years later*, and that too in spite of costly experience in the irrigation works in India of the necessity

of more knowledge in this branch of science. An extract is also given from an article in *Engineering*, Dec. 31, 1875, which says that Neville's tables of velocities based upon Dubuat, "though expressed in hundredths of an inch, are in reality but the wildest guesses at the actual velocities in irrigation canals of ordinary dimensions. Col. Cautley relied upon Dubuat when he laid out the Ganges Canal, and found him but a rotten reed, for the water in every instance tore along at an unexpected velocity, and erosion of the bed and destruction of the works followed." The writer of this article then sets aside as unreliable for such work almost all the familiar text books, both original and compiled, Continental and English, down to the time of D'Arcy and Bazin. If engineers in England have been behind the age on this subject, it is to be feared that we in America have been more so, for the Continental scientific journals of Europe (in which Kutter's work was first published) are less known and read here than in England, and are hardly enough "quoted" in our own periodicals to keep the profession at large well posted on the progress in those countries—else some of our lately issued "Hand Books" would have contained Kutter's very important results.

Kutter's *Tables* are in metrical measures, and are therefore not so convenient for use here at present, as it is to be hoped, they may be some years hence. A smaller but more comprehensive set of tables for open channels has been calculated in English feet from both Bazin's and Kutter's formulas, by Thomas Higham, Engineer of Irrigation Works in the Punjab, India, which can be recommended as convenient for use and reliable.

FRICTION BETWEEN A CORD AND PULLEY.

By I. O. BAKER.

Written for Van Nostrand's Magazine.

The method of operation, in the experiments herein detailed, was to suspend known weights to each end of a cord passing over a fixed drum, and measuring the friction directly by adding weights enough to overcome the friction. The apparatus was so arranged that the arc of contact between the cord and drum could be varied from 0° to 360°. This was accomplished by arranging an arm, which carried a pulley, so as to revolve about the drum. Separate observations were made to eliminate the friction of the pulley. In the course of the work some difficulty was found in determining exactly when the friction and added weight were in equilibrium. In all cases the mean position was the one sought. The co-efficient was computed by the well-known formula, given on page 617 of Rankine's "Analytical Mechanics," which, stated in words, is: "the ratio of the tensions of the free ends of the cord equals the base of the Naperian logarithms raised to a power indicated by the product of the co-efficient of friction and the arc of contact measured in terms of the radius."

The first series of experiments was was made upon an oak drum 4.09 inches in diameter, which had been turned in a lathe and finished with medium fine sand-paper. The cord used was a hard twisted, three strand, cotton cord, 0.08 of an inch in diameter. The arc of contact varied from 0° to 360° by steps of 10° each. All necessary corrections were made and the co-efficient computed for each angle. The results vary between .2319 and .1312, the mean of the thirty-six observations being .1599. Up to 30° the co-efficient diminished quite rapidly, while from 30° to 360° it decreased slowly as the angle increased. This is accounted for by the fact that the cord became harder under the increased tension. If we neglect four results, which vary more widely from the mean (owing probably to errors of observations) the limits then become .1679 and .1412, and

the mean .1563. The observations discarded are all from small angles.

In the second series, the conditions were the same as in the first, with the exception of the substitution of a drum whose diameter equals 1.81 inches. It was noticed that in this experiment the data agreed approximately with that of the first series to about 140°, hence the co-efficient was computed only for the twenty-one angles between 140° and 360°. The range in this case being between .1413 and .1265 and the mean .1371. For the same angles in the first series we would have a range from .1660 to .1412 with a mean of .1538.

The third series was made with a cast iron drum 3.03 inches in diameter. The surface of the drum smoothly turned but *not filed.* The cord was the same as used in the other two. Nine experiments were made at angles from 20° to 360°. The mean is .1753, the maximum .2133, and the minimum .1549.

For the fourth series the drum used in the third series was smoothly filed and observations made at the same angles as before. The mean this time is .1348, the maximum .1685, and the minimum .1089.

[The above experiments were made by Mr. C. G. Elliott in the Physical Laboratory of the Illinois Industrial University.]

THE VENTILATION OF THE MONT CENIS TUNNEL.

By WILLIAM POLE, F.R.SS. L. and E., M. Inst. C.E.

From Minutes of the Proceedings of the Institution of Civil Engineers.

In the discussion which took place at the Institution in January, 1876, on Mr. G. J. Morrison's Paper "On the ventilation and Working of Railway Tunnels," the Author mentioned, that on a visit to the Mont Cenis Tunnel in 1873, he saw some large exhausters at work at the north end, which he had reason to believe were used to effect an artificial ventilation of the tunnel. He explained however, that the information he obtained on that occasion was imperfect, and that it would be desirable to procure further data.

In the spring of 1877 he had an opportunity of again visiting the tunnel, and of obtaining the further particulars desired. The authorities of the Alta Italia railway in Turin, who have charge of the maintenance and working of the tunnel, courteously gave him all necessary facilities, and the engineer resident on the spot fully explained the works. He therefore thinks it right to make the necessary corrections and additions to his former statement, and so to put the Institution in possession of the true facts of the case.

The ventilation of the tunnel during its construction was described to the Institution by Mr. T. Sopwith, Jr., M. Inst. C.E., in his Paper of 1864; and in 1873 he added some further remarks about two years after the opening. It will be convenient therefore to take up the subject at the point where Mr. Sopwith left it.

No special works having reference to the permanent ventilation of the tunnel appear to have been included in the design. Mr. Sopwith stated there had been an expectation that, as the Italian end was 435 feet higher than the French end there would be a constant natural current established through the tunnel from north to south. But it is difficult to understand on what grounds such an expectation could have been based. It is true that the air at the southern entrance will, *cœteris paribus*, be more rarefied by about half an inch of mercury than that at the northern end; but as this rarefication is naturally due to the altitude it can have no effect in creating a current. In a pipe 435 feet long, placed vertically, the conditions would be similar, but they would cause no ascending current, as the air within the pipe would be in precisely the same condition as the external atmosphere around it. Hence the mere difference of level of the two ends of the tunnel, can, *per*

se, have no effect in producing ventilation.

This view was proved correct by experience, for, as Mr. Sopwith stated, no such current was found to exist, and the ventilation was often far from good. This evil was not of sufficient magnitude to annoy the passengers, but it was found "bad enough to render the work of the watchmen, rail-layers, and others employed in the tunnel insupportable at times."

To remedy this, advantage was taken of the air-compressing apparatus, which had been erected during the construction at Bardonnecchia, by laying a pipe about 8 inches diameter through the whole length of the tunnel, and placing cocks upon it at intervals of 125 mèters. This pipe is still used; it is always kept supplied with air compressed to about six atmospheres, so that by opening any of these cocks a stream of fresh air, cooled by its expansion, is admitted at that part of the tunnel. Whenever, therefore, after the passage of a train, a man finds himself enveloped in a bad atmosphere, he opens the nearest air-cock and is at once relieved.

The Author saw this apparatus at work, and it appears to answer the partial and local purpose intended; but it is clear that it can do nothing worth speaking of to promote general ventilation, for the whole quantity of air supplied is only about 450 cubic feet per minute, a quantity much too small to produce any effective change.

It is also found that the loud hissing noise attending the escape of the air from the small apertures has, on some occasions, endangered the lives of the men by preventing them from hearing the approach of the trains.

At the north, or French end an additional arrangement is adopted, namely, the exhausting process to which the Author alluded in his former remarks. The origin of this arrangement was as follows:—The northern half of the tunnel inclines steeply upwards from its mouth, to the center of the mountain; and as the vitiated air generated during the works of construction would not naturally descend, it was necessary to extract it by force. For this object a channel or culvert was formed at the bottom of the tunnel, below formation level, and was carried along *pari passu* with the portion of the tunnel executed from the north end. Outside the tunnel on the hill above Modane were established large exhausting pumps, which, communicating with the channel, sucked, by its means, the vitiated air from the interior of the tunnel, the fresh air supplying its place, partly from the working of the compound air machines, but chiefly by entrance at the mouth, direct from the external atmosphere.

After the tunnel was completed, and when the defects of ventilation were felt, it was resolved to retain this apparatus in action, and it is at work still.

The exhausting apparatus consists of four large bell-vessels, like small gasholders, inverted in water. These are made to rise and fall by water-power, and being furnished with inlet and outlet valves, they act as air pumps, exhausting the air from a chamber below, which is in communication with the channel under the tunnel. Each bell is 5 mèters in diameter, and works with a stroke of 2 meters, making six or eight strokes per minute. When the Author was there three of them were at work, at about six strokes per minute, and he calculated that they pumped in all nearly 25,000 cubic feet of air per minute.

The air-exhaust channel under the tunnel is of rectangular shape, 1 square mèter in area, and it has apertures at intervals of 500 meters, capable of being closed and opened at pleasure. Usually those nearest the mouth are closed, and the more distant ones open, so as to draw away the air as far in as possible; but the men open any of them when they find it necessary to clear a particular spot. Of course the fresh air enters from the mouth of the tunnel to supply the place of what is removed by the exhaustion. The Author inquired what was the practical effect of this exhausting process, and he was told that it was insufficient and unsatisfactory. The apertures nearest to the mouth were found to draw very well, but at a further distance away little or no draught was perceived, and consequently the process had no beneficial operation where it was wanted, that is, near the middle of the tunnel.

On examining the mechanical conditions of the problem, this disappointment is easily accounted for. The quan-

tity of air extracted gives a velocity along the exhaust-conduit of about 40 feet per second, and to overcome the frictional resistance due to this, over a length of several miles, would require much more power than the bell-pumps are able to afford. Their exhaustive force is only about 20 inches of water (100 lbs. per square foot), and they are incapable of doing more without exceeding their hydraulic seal. Hence, under the given conditions, the exhaustion can only act during the first mile or two of the tunnel, leaving all beyond unaffected.

From the foregoing description it may be inferred that the artificial processes of supplying compressed air at the Italian end, and of exhausting the air at the French end, although of some use locally and partially, can have no important influence in producing any thorough ventilation of the tunnel.

In the face, however, of this inference one is met with the undeniable fact that somehow or other, a considerable amount of general ventilation does go on. There must be a large quantity of vitiated air produced by the frequent passage of powerful engines, and yet it is not found that the passengers are incommoded thereby; on the contrary, they generally testify to the pleasantness of the atmosphere in passing through. Hence, although as before stated, inconvenience is found by the men immediately after the passage of trains, it is clear that a sufficient general movement must go on to effect, after a time, the entire removal of the noxious vapors. It will be interesting to inquire how this can be explained.

The mechanical action of the moving trains may be left out of the question; it would have no preceptible influence in moving the great mass of the contents of the tunnel, and in all probability the air only slips by them from the front to behind as they pass along.

It has been already remarked, too, that no current can be due to the mere difference of level of the two ends; but it may happen and no doubt does happen, that, independently of this, the barometric condition of the atmosphere generally may be different on the two sides of the Alps, and a very slight difference in this respect would suffice to create a powerful draught. Thus, if the air pressure, at the same altitude above sea-level, differs on the two sides of the mountain by only $\frac{1}{10}$ of an inch of mercury, this would suffice to create a current through the tunnel of $7\frac{1}{2}$ miles an hour. And there is no doubt that, from the very variable meteorological conditions in these high regions, such differences, or even much greater ones, must often occur. A difference of $\frac{1}{2}$ an inch of mercury would generate a current of 16 miles an hour.

In addition to this there is also the effect of the wind, as a brisk gale blowing from the north or the south, as the case may be, would have sufficient force to give rise to some current through. These meteorological conditions would no doubt vary much at different periods; sometimes they would act very powerfully, at other times they would not act at all. All this fully accounts for the the statment made by Mr. Sopwith from personal experience. He said "The difference in the rates of the air currents was very remarkable. During a few days he spent in the tunnel, on one day the air was almost stagnant, and on the following day he could hardly keep his hat on." This is just what might be expected from currents produced by meteorological changes.

There is, however, another cause of spontaneous ventilation which is always at work, with much more regularity, namely the *heating of the air inside the tunnel.* In regard to this, the difference of level of the two ends becomes a very material feature; the tunnel in fact assumes the function of a ventilating chimney 435 feet high; and when its contents are rarefied by heating, the production of an ascending current from north to south is perfectly natural. The heating of the air may occur in two ways: it may partly be caused by the higher temperature of the walls; for although the theories at first held as to the supposd high temperature of the interior of the mountain have not been borne out by experience, yet the heat is, no doubt, something greater than that outside. But the chief source of the heat will be the working of the engines; and it is matter of fact, that the general temperature inside the tunnel is maintained at a much higher degree than the external air at

the ends. According to Mr. Sopwith, this temperature may be estimated at 83° to 90° Fahr., which would give an elevation of from 30° to 60°; and calculation will show that, assuming all the air in the tunnel to be heated to this extent, it would suffice to establish a permanent current from Modane to Bardonnecchia.

The Author had, when he last came through the tunnel, from south to north, a practical proof of the existence of such a current; for although another train had shortly before gone up from Modane, filling the inclined part with smoke and vapor, yet as he approached the Modane end he found the atmosphere perfectly sweet and clear, the whole of the foulness having in the short interval been carried away.

These three causes, then, namely the difference in the barometer on the two sides, the wind, and the elevation of temperature inside the tunnel, appear in the aggregate to be effective at present in keeping up a fairly good spontaneous ventilation. The traffic, however, is not large, there being in all only twenty-two regular trains per day passing through. When this traffic is much increased, it may probably be necessary to do something to improve the ventilation by artificial means.

In reasoning from this case to others, it must be borne in mind that one of the causes of the present spontaneous ventilation (and probably the most active one) depends on the inclination of the tunnel. In such a case as that of the St. Gothard, which is nearly level, this cause cannot operate, and the Author is not aware what means are relied on for producing ventilation. The tunnel is a mile or two longer than that of Mont Cenis, and of course the difficulties will be proportionately increased.

THE DETERMINATION OF ROCKS—PORPHYRY.

By MELVILLE ATWOOD, F. G. S.

From "Journal of Microscopy."

The generally accepted meaning of the term porphyry, without addition or qualification, denotes "quartz porphyry," a plutonic rock, with a compact matrix or ground mass, consisting of quartz and feldspar, with crystals of both, having a specific gravity of from 2.5 to 2.6, and containing from 75 to 85 per cent. of silica.

What rock the Comstock miners mean when they say porphyry it would be exceedingly difficult for any one to tell. In reading over the published reports of the different Superintendents, they appear to be *continually* meeting with it at all depths, and to the east and west of the different bodies; also in the shape of "horse," or dead ground, mixed with the vein matter, and called "bird's eye porphyry." Now in ninety-nine cases out of the hundred, what they call porphyry does not in any one respect resemble that rock, lacking by 25 per cent the required amount of silica, and having no free quartz. A very slight examination by any one having only a rudimentary knowledge of geology would show that the term porphyry, so applied, is the most unappropriate that could be used to describe either the west or east country rock of the Virginia portion of the great Comstock Lode. The only way I can account for the use of that term is that they prefer it to saying "country rock."

I hardly think it requires me to say how desirable it would be, indeed, necessary, for those conducting explorations and trials on the Comstock Range, to know and be able to distinguish the different rocks they meet with in their operations, particularly as those rocks enclose some of the richest mines yet discovered in the world, and since the cost of those very explorations amount annually to millions and millions of dollars.

It may be urged that the geographical maps of the explorations of the fortieth parallel contain most of the necessary information. I would recommend those who think so to examine the maps, or any of the cross sections of the workings

on the Comstock, beautifully drawn—the work, I believe, of Mr. Stretch, but colored by the officers of the Survey, and they will find that the Mount Davidson diorite is colored as syenite, and the black dyke, a dolorite as andesite. Most of the country rocks overlaying the Comstock on the east are marked as propylite and andesite. The second propylite and andesite are identical in chemical and mineralogical composition, and a slight inspection of the Sutro Tunnel and other drainage levels will show that petrologically they are the same, in fact, the only difference being that the former occurs in sheets and the latter in dykes. When the feldspar in the so-called propylite is very much kaolinized, the rock is sometimes termed by the miners bird's eye porphyry. It may be said that the new work by Ferdinand Zirkel, "Microscopical Petrography," corrects most of those errors, by admitting in the first place that the Mount Davidson rock is a diorite. No mention, however, or section, is given of one of the most important rocks of the Comstock range, the black dyke; and in the explanation of the beautifully colored plates, he has neglected to state the number of times they are magnified. This is a most unfortunate omission, particularly so with respect to the basaltic rocks. My attention was called to it by some remarks in one of the Virginia papers, wherein it was stated that one of the handsome colored plates was a section of basalt from American Flat. Now, dolorite, anamesite and basalt, are, in a mineralogical point of view, the same rock, differing only in the fineness of texture.

The following are the approximate measurements of the crystals of feldspar in these rocks:

In the Black Dyke, they average from 7-600 to 20-600 in length, by 1-1200 to 10-1200 in width.

In the Dolerite, they are of irregular shape, but generally about double the size of those in the Black Dyke; while there are small masses containing small needle-shaped crystals 1-300 to 4-300 in length.

In the Basalt they average from 4-1200 to 9-1200 long, by 1-1200 to 2-1200 in width.

Eight pages, however, in that work, with a colored section, are devoted to what is called "Augite Andesite." Now though I have taken a great deal of trouble, as yet I have not been able to procure a single specimen of that rock called Andesite. A few months ago, a good authority on such matters, Alphons Stubel, of Dresden, passed through this city on his way home from South America, where he had been collecting rocks for many years. Knowing that he had been at Chimborazo, I thought it would be a good opportunity to get what I wanted; so when he called upon me I asked him as a favor to give me a specimen of andesite. He said that he was very sorry he could not comply with my request, that he really did not know any such rock.

I am fully aware that looseness in petrological nomenclature is the rule and not the exception, and that many geologists are found writing of totally different rocks under one and the same name. I do not think that any distinction between rocks is worth much unless it can be applied in the field. I have stated that the black dyke, a dolorite, but which from the fineness of its texture might be called anamesite, was one of the most important rocks in connection with the Comstock mines, from the fact that it forms the west boundary to all the vast treasures of the Comstock, no ore worth mentioning ever having been found at the west side of it; therefore every miner conducting operations in that district ought to possess the necessary amount of knowledge to enable him to distinguish that rock. If you will look at No. 12 rock and section, you will find it is fine-grained and apparently of so homogeneous a texture as not to admit of its constituent minerals being resolved by the naked eye. I have quite a collection of specimens which have been given to me, supposing them to be that rock.

In 1867, when engaged in the examination of the gold mines of North Wales, the well-known mining engineer, Mr. A. Dean, gave me the rough tracing of the working plans of the St. David's mine, Clogan, near Dolgelley, and which I have brought for your inspection. The geological features of that district are the Cambrian rocks, overlaid by the lower silurian. The St. David's vein is partly in the silurian slate beds, and sheets of

greenstone (diabase) lying between the slates, and partly in the Cambrians. What I particularly wish to draw your attention to, however, is the transverse section, showing the gold-bearing and non-gold-bearing rocks of the Clogan mines, and the very important fact that only those portions of the veins were rich in gold, or productive, where the walls were greenstone

Impressed with the truth of the discovery, on my return to California I devoted a large portion of my time to the examination of the enclosing and wall rocks of the gold and silver bearing veins of this Coast. On the formation of this Society, I availed myself of the aid of a microscope to carry on my investigations, but soon found out that to do so with anything like satisfactory result I must get a collection of well authenticated foreign types, to compare with and guide me in the work. Through the kindness of the late Mr. David Forbes, of London, Dr. Hector, of New Zealand, and, in San Fransisco, of Mr. H. G. Hanks and Mr. Charles Schneider, I have now a collection of some 500 specimens of foreign types, from which, with the assistance of my son, I have cut between 1,400 and 1,500 sections—some of them very roughly done. I found it necessary to have two or three from each specimen, some cut very thin and others rather thick, to show color and for examination with the aid of a parabolic illuminator. My collection of rock sections from this Coast is large; but the result of it all amounts to this; I found that every step I took I was traveling on a road that led me far away from what I wanted, which was, a method to make it easy for my fellow miners to understand and distinguish the enclosing and wall rocks of the different lodes they were working—these rocks having so much to do with the productivenes of the lodes.

By the merest chance, I have found out a simple way which I think, in a great measure, will partly fill the gap so much needed.

The different pieces of rock which I now present to the Society are roughly prepared after this method, and made so that an inspection of the outer surface viewed as an opaque object, with only the aid of a common hand-magnifier, will give all the information ordinarily required by the miner, and in most cases he will find that he is able to distinguish the structure and composition of all the commoner rocks, so that with the help of a small collection of foreign types, prepared after the same fashion, he can compare and identify those under examination. It will be necessary for them to read up a little on the subject, and to acquire a rudimentary knowledge of geology, which I think can be best done by a careful study of such works as "The Student's Manual of Geology," by J. Beete Jukes, 1857; "Text Book of Geology," by Dana; "A System of Mineralogy," by Dana; "A Treatise on Lithology," by Van Cotta, English Edition, by P. H. Lawrence; and "Determination of Rocks," by E. Jannettaz, translated by Plympton.

The rock for examination may be prepared as follows: First wash the specimen clean, using a brush to get rid of any clay and dirt; then select the side or part you wish to examine, and grind it down on a piece of sandstone (a shoemaker's sharpening stone) until a perfectly flat surface is obtained. This will occupy but a few minutes, unless the rock is very hard. The surface should then be worked down still finer with a square emery file, using water, and after you have obtained a sufficient polish, wash the rock again, and then let it dry gradually, either on a stove, or, what is better still, a little brass table, with a spirit lamp, the same that is used for heating slides. When perfectly dry, heat it again to a point, so that you can barely handle it; then polish the varnished side while hot with a mixture of one part of Canada balsam to three parts of alcohol, which must be warmed before applying it, and laid on with a camel's hair brush. It will soon dry, and if left for a day or two will harden, so that you can handle it without injury.

The effect of this treatment is remarkable, particularly on the lavas, as you will see by the specimen of trachyte lava from Bodie, which I now present to the Society.

In conclusion, it is with great hesitation that I have ventured to bring this matter before you, but I do so, well knowing that more searching and exact methods of investigation are now demanded by those conducting large mining opera-

tions, and that such terms as porphyry, for any and all enclosing, or wall rock, that may be met with in such mines as the Comstock, and the term green chlorides for the rich ore will not be deemed a sufficient explanation, or tend to give the mine adventurers that confidence in the reports of their employees which they should be entitled to, particularly when it is known that the rock is not porphyry, and that the chloride of silver is one of the accidental minerals met with in vein matter.

I am in hopes that by thus breaking the ice, others more capable in every respect than myself will be induced to communicate the results of their researches on the subject.

All that can be claimed for the mode I have suggested to you for the examination of rocks is that it is a rude and simple way of determining some of the commoner ones, but the application of the microscope, even now quite in its infancy, is, after all, what we must trust to for exact or reliable results.

MATHEMATICAL SCIENCE.

Abstract of the Address of Mr. WM. SPOTTISWOODE to the British Association.

From "The Engineer."

Although in its technical character mathematical science suffers the inconveniences, while it enjoys the dignity, of its Olympian position, still in a less formal garb, or in disguise, if you are pleased so to call it, it is found present at many an unexpected turn; and although some of us may never have learnt its special language, not a few have, all through our scientific life, and even in almost every accurate utterance, like Molière's well-known character, been talking mathematics without knowing it. It is, moreover, a fact not to be overlooked, that the appearance of isolation, so conspicuous in mathematics, appertains in a greater or less degree to all other sciences, and perhaps also to all pursuits in life. In its highest flight each soars to a distance from its fellows. Each is pursued alone for its own sake, and without reference to its connection with, or its application to, any other subject. The pioneer and the advanced guard are of necessity separated from the main body, and in this respect mathematics does not materially differ from its neighbors. And, therefore, as the solitariness of mathematics has been a frequent theme of discourse, it may be not altogether unprofitable to dwell for a short time upon the other side of the question, and to inquire whether there be not points of contact in method or in subject-matter between mathematics and the outer world which have been frequently overlooked; whether its lines do not in some cases run parallel to those of other occupations and purposes of life; and lastly, whether we may not hope for some change in the attitude too often assumed towards it by the representatives of other branches of knowledge and of mental activity. In his preface to the "Principia" Newton gives expression to some general ideas which may well serve as the key-note for all future utterances on the relation of mathematics to natural, including also therein what are commonly called artificial, phenomena. "The ancients divided mechanics into two parts, rational and practical; and since artisans often work inaccurately, it came to pass that mechanics and geometry were distinguished in this way, that everything accurate was referred to geometry, and everything inaccurate to mechanics. But the inaccuracies appertain to the artisan and not to the art, and geometry itself has its foundation in mechanical practice, and is in fact nothing else than that part of universal mechanics which accurately lays down and demonstrates the art of measuring." He next explains that rational mechanics is the science of motion resulting from forces, and adds: "The whole difficulty of philosophy seems to me to lie in investigating the forces of nature from the phenomena of

motion, and in demonstrating that from these forces other phenomena will ensue." Then, after stating the problems of which he has treated in the work itself, he says, "I would that all other natural phenomena might similarly be deduced from mechanical principles. For many things move me to suspect that everything depends upon certain forces in virtue of which the particles of bodies, through forces not yet understood, are either impelled together so as to cohere in regular figures, or are repelled and recede from one another." Newton's views, then, are clear. He regards mathematics, not as a method independent of, though applicable to, various subjects, but is itself the higher side or aspect of the subjects themselves; and it would be little more than a translation of his notions into other language, little more than a paraphrase of his own words, if we were to describe the mathematical as one aspect of the material world itself, apart from which all other aspects are but incomplete sketches, and however accurate after their own kind, are still liable to the imperfections of the inaccurate artificer. Mr. Burrowes, in his Preface to the first volume of the "Transactions of the Royal Irish Academy," has carried out the same argument, approaching it from the other side. "No one science," he says, "is so little connected with the rest as not to afford many principles whose use may extend considerably beyond the science to which they primarily belong, and no proposition is so purely theoretical as to be incapable of being applied to practical purposes. There is no apparent connection between duration and the cycloidal arch, the properties of which have furnished us with the best method of measuring time; and he who has made himself master of the nature and affections of the logarithmic curve has advanced considerably towards ascertaining the proportionable density of the air at various distances from the earth. The researches of the mathematician are the only sure ground on which we can reason from experiments; and how far experimental science may assist commercial interests is evinced by the success of manufacturers in countries where the hand of the artificer has taken its direction from the philosopher. Every manufacture is in reality but a chemical process, and the machinery requisite for carrying it on but the right application of certain propositions in rational mechanics." So far your academician. Every subject, therefore, whether in its usual acceptation, scientific, or otherwise, may have a mathematical aspect; as soon, in fact, as it becomes a matter of strict measurement, or of numerical statement, so soon does it enter upon a mathematical phase. This phase may, or it may not, be a prelude to another in which the laws of the subject are expreessed in algebraical formulæ or represented by geometrical figures. But the real gist of the business does not always lie in the mode of expression, and the fascination of the formulæ or other mathematical paraphernalia may after all be little more than that of a theatrical transformation scene. The process of reducing to formulæ is really one of abstraction, the results of which are not always wholly on the side of gain; in fact, through the process itself the subject may lose in one respect even more than it gains in another. But long before such abstraction is completely attained, and even in cases where it is never attained at all, a subject may to all intents and purposes become mathematical. It is not so much elaborate calculations or abstruse processes which characterize this phase as the principles of precision, of exactness, and of proportion. But these are principles with which no true knowledge can entirely dispense. If it be the general scientific spirit which at the outset moves upon the face of the waters, and out of the unknown depth brings forth light and living forms, it is no less the mathematical spirit which breathes the breath of life into what would otherwise have ever remained mere dry bones of fact, which re-unites the scattered limbs and re-creates from them a new and organic whole. And as a matter of fact, in the words used by Professor Jellett at our meeting at Belfast, viz., "Not only are we applying our methods to many sciences already recognized as belonging to the legitimate province of mathematics, but we are learning to apply the same instrument to sciences hitherto wholly or partially independent of its authority. Physical science is learning

more and more every day to see in the phenomena of nature modifications of that one phenomenon—namely, motion—which is peculiarly under the power of mathematics." Echoes are these, far off and faint perhaps, but still true echoes, in answer to Newton's wish that all these phenomena may some day "be deduced from mechanical principles." If turning from this aspect of the subject, it were my purpose to enumerate how the same tendency has evinced itself in the arts, unconsciously it may be to the artists themselves, I might call as witnesses each one in turn with full reliance on the testimony which they would bear. And, having more special reference to mathematics, I might confidently point to the accuracy of measurement, to the truth of curve, which, according to modern investigation, is the key to the perfection of classic art. I might triumphantly cite not only the architects of all ages, whose art so manifestly rests upon mathematical principles; but I might cite also the literary as well as the artistic remains of the great artists of Cinquecento, both painters and sculptors, in evidence of the geometry and the mechanics which, having been laid at the foundation, appear to have found their way upwards through the superstructure of their works. And in a less ambitious sphere, but nearer to ourselves in both time and place, I might point with satisfaction to the great school of English constructors of the eighteenth century in the domestic arts; and remind you that not only the engineer and the architect, but even the cabinetmakers devoted half the space of their books to perspective and to the principles whereby solid figures may be delineated on paper, or what is now termed descriptive geometry. Nor perhaps would the sciences which concern themselves with reasoning and speech, nor the kindred art of music, nor even literature itself, if thoroughly probed, offer fewer points of dependence upon the science of which I am speaking. What, in fact, is logic but that part of universal reasoning; grammar but that part of universal speech; harmony and counterpoint but that part of universal music; "which accurately lays down," and demonstrates—so far as demonstration is possible—precise methods appertaining to each of these arts? And I might even appeal to the common consent which speaks of the mathematical as the pattern form of reasoning and model of a precise style. Taking, then, precision and exactness as the characteristics which distinguish the mathematical phase of a subject, we are naturally led to expect that the approach to such a phase will be indicated by increasing application of the principle of measurement, and by the importance which is attached to numerical results. And this very necessary condition for progress may, I think, be fairly described as one of the main features of scientific advance in the present day. If it were my purpose, by descending into the arena of special sciences, to show how the most varied investigations alike tend to issue in measurement, and to that extent to assume a mathematical phase, I should be embarrassed by the abundance of instances which might be adduced. I will, therefore, confine myself to a passing notice of a very few, selecting those which exemplify not only the general tendency, but also the special character of the measurements now particularly required, viz., that of minuteness, and the indirect method by which alone we can at present hope to approach them. An object having a diameter of an 80,000th of an inch is perhaps the smallest of which the microscope could give any well-defined representation; and it is improbable that one of 120,000th of an inch could be singly discerned with the highest powers at our command. But the solar beams and the electric light reveal to us the presence of bodies far smaller than these. And, in the absence of any means of observing them singly, Professor Tyndall has suggested a scale of these minute objects in terms of the lengths of luminiferous waves. To this he was led, not by any attempt at individual measurement, but by taking account of them in the aggregate, and observing the tints which they scatter laterally when clustered in the form of actinic clouds. The small bodies with which experimental science has recently come into contact are not confined to gaseous molecules, but comprise also complete organisms; and the same philosopher has made a profound study of the momentous influence exerted by these

minute organisms in the economy of life. And if, in view of their specific effects, whether deleterious or other, on human life, any qualitative classification, or quantitative estimate be ever possible, it seems that it must be effected by some such method as that indicated above. Again, to enumerate a few more instances of the measurement of minute quantities, there are the average distances of molecules from one another in various gases and at various pressures; the length of their free path, or range open for their motion without coming into collision; there are movements causing the pressures and differences of pressure under which Mr. Crookes' radiometers execute their wonderful revolutions. There are the excursions of the air while transmitting notes of high pitch, which through the researches of Lord Rayleigh appear to be of a diminutiveness altogether unexpected. There are the molecular actions brought into play in the remarkable experiments by Dr. Kerr, who has succeeded, where even Faraday failed, in effecting a visible rotation of the plane of polarisation of light in its passage through electrified dielectrics, and on its reflexion at the surface of a magnet. To take one more instance, which must be present to the minds of us all, there are the infinitesimal ripples of the vibrating plate in Mr. Graham Bell's most marvelous invention. Of the nodes and ventral segments in the plate of the telephone which actually convert sound into electricity and electricity into sound, we can at present form no conception. All that can now be said is that the most perfect specimens of Chladni's sand figures on a vibrating plate, or of Kundt's lycopodium heaps in a musical tube, or even Mr. Sedley Taylor's more delicate voitices in the films of the phoneidoscope, are rough and sketchy compared with these. For notwithstanding the fact that in the movement of the telephone plate we have actually in our hand the solution of that old world problem, the construction of a speaking machine; yet the characters in which that solution is expressed are too small for our powers of decipherment. In movements such as these we seem to lose sight of the distinction, or perhaps we have unconsciously passed the boundary between massive and molecular motion. Through the phonograph we have not only a transformation but a permanent and tangible record of the mechanism of speech. But the differences upon which articulation (apart from loudness, pitch, and quality) depends, appear from the experiments of Fleemin Jenkin and of others to be of microscopic size. The microphone affords another instance of the unexpected value of minute variations—in this case of electric currents; and it is remarkable that the gist of the instrument seems to lie in obtaining and perfecting that which electricians have hitherto most scrupulously avoided, viz., loose contact. Once more, Mr. De La Rue has brought forward as one of the results derived from his stupendous battery of 10,000 cells, strong evidence for supposing that a voltaïc discharge, even when apparently continuous, may still be an intermittent phenomenon; but all that is known of the period of such intermittence is, that it must recur at exceedingly short intervals. And in connection with this subject, it may be added that, whatever be the ultimate explanation of the strange stratification which the voltaic discharge undergoes in rarefied gases, it is clear that the alternate disposition of light and darkness must be dependent on some periodic distribution in space or sequence in time which can at present be dealt with only in a very general way. In the exhausted column we have a vehicle for electricity not constant like an ordinary conductor, but itself modified by the passage of the discharge, and perhaps subject to laws differing materially from those which it obeys at atmospheric pressure. It may also be that some of the features accompanying stratification from a magnified image of phenomena belonging to disruptive discharges in general; and that consequently, so far from expecting among the known facts of the latter any clue to an explanation of the former, we must hope ultimately to find in the former an elucidation of what is at present obscure in the latter. A prudent philosopher usually avoids hazarding any forecast of the practical application of a purely scientific research. But it would seem that the configuration of these striæ might some day prove a very delicate means of estimating low pressures. Now,

it is a curious fact that almost the only small quantities of which we have as yet any actual measurements are the wave lengths of light; and that all others, excepting so far as they can be deduced from these, await future determination. In the meantime, when unable to approach these small quantities individually, the method to which we are obliged to have recourse is, as indicated above, that of averages, whereby, disregarding the circumstances of each particular case, we calculate the average size, the average velocity, the average direction, &c., of a large number of instances. But although this method is based upon experience, and leads to results which may be accepted as substantially true; although it may be applicable to any finite interval of time, or over any finite area of space (that is, for all practical purposes of life), there is no evidence to show that it is so when the dimensions of interval or of area are indefinitely diminished. The truth is that the simplicity of nature which we at present grasp is really the result of infinite complexity; and that below the uniformity there underlies a diversity whose depths we have not yet probed, and whose secret places are still beyond our reach. The present is not an occasion for multiplying illustrations, but I can hardly omit a passing allusion to one all-important instance of the application of the statistical method. Without its aid social life, or the history of life and death, could not be conceived at all, or only in the most superficial manner. Without it we could never attain to any clear ideas of the condition of the poor, we could never hope for any solid amelioration of their condition or prospects Without its aid, sanitary measures, and even medicine would be powerless. Without it, the politician and the philanthropist would alike be wandering over a trackless desert. It is, however, not so much from the side of science at large as from that of mathematics itself, that I desire to speak. I wish from the latter point of view to indicate connections between mathematics and other subjects, to prove that hers is not after all such a far-off region, nor so undecipherable an alphabet, and to show that even at unlikely spots we may trace under-currents of thought which having issued from a common source fertilise alike the mathematical and the non-mathematical world. Having this in view, I propose to make the subject of special remark some process peculiar to modern mathematics; and, partly with the object of incidentally removing some current misapprehensions, I have selected for examination three methods in respect of which mathematicians are often thought to have exceeded all reasonable limits of speculation, and to have adopted for unknown purposes an unknown tongue. And it will be my endeavor to show not only that in these very cases our science has not outstepped its own legitimate range, but that even art and literature have unconsciously employed methods similar in principle. The three methods in question are, first, that of imaginary quantities; secondly, that of manifold space; and thirdly, that of geometry not according to Euclid. First it is objected that, abandoning the more cautious methods of ancient mathematicians, we have admitted into our formulæ quantities which by our own showing, and even in our own nomenclature, are imaginary or impossible; nay, more, that out of them we have formed a variety of new algebras to which there is no counterpart whatever in reality, but from which we claim to arrive at possible and certain results. On this head it is in Dublin, if anywhere, that I may be permitted to speak. For to the fertile imagination of the late Astronomer Royal for Ireland we are indebted for that marvellous Calculus of Quaternions, which is only now beginning to be fully understood, and which has not yet received all the applications of which it is doubtless capable. And even although this calculus be not co-extensive with another which almost simultaneously germinated on the Continent, nor with ideas more recently developed in America, yet it must always hold its position as an original discovery, and as a representative of one of the two great groups of generalized algebras—viz., those the squares of whose units are respectively negative, unity and zero—the common origin of which must still be marked on our intellectual map as an unknown region. Well do I recollect how in its early days we used to handle the method as a magician's page might

try to wield his master's wand, trembling as it were between hope and fear, and hardly knowing whether to trust our own results until they had been submitted to the present and ever-ready counsel of Sir W. R. Hamilton himself. To fix our ideas, consider the measurement of a line, or the reckoning of time, or the performance of any mathematical operation. A line may be measured in one direction or in the opposite; time may be reckoned forward or backward; an operation may be performed or be reversed, it may be done or may be undone ; and if having once reversed any of these processes we reverse it a second time, we shall find that we have come back to the original direction of measurement or of reckoning, or to the original kind of operation. Suppose, however, that at some stage of a calculation our formulæ indicate an alteration in the mode of measurement such that, if the alteration be repeated, a condition of things, not the same as, but the reverse of the original, will be produced. Or suppose that, at a certain stage, our transformations indicate that time is to be reckoned in some manner different from future or past, but still in a way having definite algebraical connection with time which is gone and time which is to come. It is clear that in actual experience there is no process to which such measurements correspond. Time has no meaning except as future or past; and the present is but the meeting point of the two. Or, once more, suppose that we are gravely told that all circles pass through the same two imaginary points at an infinite distance, and that every line drawn through one of these points is perpendicular to itself. On hearing the statement, we shall probably whisper, with a smile or a sigh, that we hope it is not true; but that in any case it is a long way off, and perhaps, after all, it does not very much signify. If, however, as mathematicians we are not satisfied to dismiss the question on these terms, we ourselves must admit that we have here reached a definite point of issue. Our science must either give a rational account of the dilemma, or yield the position as no longer tenable. Special modes of explaining this anomalous state of things have occurred to mathematicians. But, omitting details as unsuited to the present occasion, it will, I think, be sufficient to point out in general terms that a solution of the difficulty is to be found in the fact that the formulæ which give rise to these results are more comprehensive than the signification assigned to them ; and when we pass out of the condition of things first contemplated they cannot—as it is obvious they ought not—give us any results intelligible on that basis. But it does not therefore by any means follow that upon a more enlarged basis the formulæ are incapable of interpretation; on the contrary, the difficulty at which we have arrived indicates that there must be some more comprehensive statement of the problem which will include cases impossible in the more limited, but possible in the wider view of the subject. A very simple instance will illustrate the matter. If from a point outside a circle we draw a straight line to touch the curve, the distance between the starting point and the point of contact has certain geometrical properties. If the starting point be shifted nearer and nearer to the circle the distance in question becomes shorter, and ultimately vanishes. But as soon as the point passes to the interior of the circle the notion of a tangent and distance to the point of contact cease to have any meaning; and the same anomalous condition of things prevail, as long as the point remains in the interior. But if the point be shifted still further until it emerges on the other side, the tangent and its properties resume their reality, and are as intelligible as before. Now the process whereby we have passed from the possible to the impossible, and again repassed to the possible (namely, the shifting of the starting point) is a perfectly continuous one, while the conditions of the problem as stated above have abruptly changed. If, however, we replace the idea of a line touching by that of a line cutting the circle, and the distance of the point of contact by the distances at which the line is intercepted by the curve, it will easily be seen that the latter includes the former as a limiting case, when the cutting line is turned about the starting point until it coincides with the tangent itself. And further, that the two intercepts have a perfectly distinct and intelligible meaning whether the point be outside or inside the area.

The only difference is that in the first case the intercepts are measured in the same direction; in the latter in opposite directions. The foregoing instance has shown one purpose which these imaginaries may serve, viz., as marks indicating a limit to a particular condition of things, to the application of a particular law, or pointing out a stage where a more comprehensive law is required. To attain to such a law we must, as in the instance of the circle and tangent, reconsider our statement of the problem; we must go back to the principle from which we set out, and ascertain whether it may not be modified or enlarged. And even if in any particular investigation, wherein imaginaries have occurred, the most comprehensive statement of the problem of which we are at present capable fails to give an actual representation of these quantities; if they must for the present be relegated to the category of imaginaries; it still does not follow that we may not at some future time find a law which will endow them with reality, nor that in the mean time we need hesitate to employ them, in accordance with the great principle of continuity, for bringing out correct results. If, moreover, both in geometry and in algebra we occasionally make use of points or of quantities, which from our present outlook have no real existence, which can neither be delineated in space of which we have experience, nor measured by scale as we count measurement; if these imaginaries, as they are termed, are called up by legitimate processes of our science; if they serve the purpose not merely of suggesting ideas, but of actually conducting us to practical conclusions; if all this be true in abstract science, I may perhaps be allowed to point out, in illustration of my argument, that in art unreal forms are frequently used for suggesting ideas, for conveying a meaning for which no others seem to be suitable or adequate. Are not forms unknown to biology, situations incompatible with gravitation, positions which challenge not merely the stability but even the possibility of equilibrium—are not these the very means to which the artist often has recourse in order to convey his meaning and to fulfill his mission? Who that has ever revelled in the ornamentation of the Renaissance, in the extraordinary transitions from the animal to the vegetable, from faunic to floral forms, and from these again to almost purely geometric curves, who has not felt that these imaginaries have a claim to recognition very similar to that of their congeners in mathematics? How is it that the grotesque paintings of the middle ages, the fantastic sculpture of remote nations, and even the rude art of the pre-historic past, still impress us, and have an interest over and above their antiquarian value; unless it be that they are symbols which, although hard of interpretation when taken alone, are yet capable, from a more comprehensive point of view, of leading us mentally to something beyond themselves, and to truths which, although reached through them, have a reality scarcely to be attributed to their outward forms? Again, if we turn from art to letters, truth to nature and to fact is undoubtedly a characteristic of sterling literature; and yet in the delineation of outward nature itself, still more in that of feelings and affections, of the secret parts of character and motives of conduct, it frequently happens that the writer is driven to imagery, to an analogy, or even to a paradox, in order to give utterance to that of which there is no direct counterpart in recognized speech. And yet which of us cannot find a meaning for these literary figures, an inward response to imaginative poetry, to social fiction, or even to those tales of giant and fairyland, written, it is supposed, only for the nursery or schoolroom? But in order thus to reanimate these things with a meaning beyond that of the mere words, have we not to reconsider our first position, to enlarge the ideas with which we started; have we not to cast about for something which is common to the idea conveyed and to the subject actually described, and to seek for the sympathetic spring which underlies both; have we not, like the mathematician, to go back as it were to some first principles, or, as it is pleasanter to describe it, to become again as a little child? Passing to the second of the three methods, viz., that of manifold space, it may first be remarked that our whole experience of space is in three dimensions, viz., of that which has length, breadth, and thickness; and if for certain purposes we restrict our ideas

to two dimensions as in plane geometry, or to one dimension as in the division of a straight line, we do this only by consciously and of deliberate purpose setting aside, but not annhilating, the remaining one or two dimensions. Negation, as Hegel has justly remarked, implies that which is negatived, or as he expresses it, affirms the opposite. It is by abstraction from previous experience, by a limination of its results, and not by independent process, that we arrive at the idea of space whose dimensions are less than three. It is doubtless on this account that problems in plane geometry which, although capable of solution on their own account, become much more intelligible, more easy of extension, if viewed in connection with solid space, and as special cases of corresponding problems in solid geometry. So eminently is this the case, that the very language of the more general method often leads us almost intuitively to conclusions which, from the more restricted point of view, require long and laborious proof. Such a change in the base of operations has, in fact, been successfully made in geometry of two dimensions, and although we have not the same experimental data for further steps, yet neither the modes of reasoning, nor the validity of its conclusions, are in any way affected by applying an analogous mental process to geometry of three dimensions; and by regarding figures in space of three dimensions as sections of figures in space of four, in the same way that figures in plano are sometimes considered as sections of figures in solid space. The addition of a fourth dimension to space not only extends the actual properties of geometrical figures, but it also adds new properties which are often useful for the purposes of transformation or of proof. Thus it has recently been shown that in four dimensions a closed material shell could be turned inside out by simple flexure, without either stretching or tearing; and that in such a space it is impossible to tie a knot. Again, the solution of problems in geometry is often effected by means of algebra; and as three measurements, or co-ordinates as they are called, determine the position of a point in space, so do three letters or measurable quantities serve for the same purpose in the language of algebra. Now, many algebraical problems involving three unknown or variable quantities admit of being generalized so as to give problems involving many such quantities. And as, on the other hand, to every algebraical problem involving unknown quantities or variables by ones, or by twos, or by threes, there corresponds a problem in geometry of one or of two or of three dimensions; so on the other it may be said that to every algebraical problem involving many variables there corresponds a problem in geometry of many dimensions. There is, however, another aspect under which even ordinary space presents to us a four-fold, or indeed a mani-fold character. In modern physics, space is regarded not as a vacuum in which bodies are placed and forces have play, but rather as a plenum with which matter is co-extensive. And, from a physical point of view, the properties of space are the properties of matter, or of the medium which fills it. Similarly from a mathematical point of view, space may be regarded as a *locus in quo*, as a plenum, filled with those elements of geometrical magnitude which we take as fundamental. These elements need not always be the same. For different purposes different elements may be chosen; and upon the degree of complexity of the subject of our choice will depend the internal structure or manifoldness of space. Thus beginning with the simplest case, a point may have any singly infinite multitude of positions in a line, which gives a one-fold system of points in a line. The line may revolve in a plane about any one of its points, giving a two-fold system of points in a plane; and the plane may revolve about any one of the lines, giving a three-fold system of points in space. Suppose, however, that we take a straight line as our element, and conceive space as filled with such lines. This will be the case if we take two planes, *e.g.*, two parallel planes, and join every point in one with every point in the other. Now the points in a plane form a two-fold system, and it therefore follows that the system of lines is four-fold; in other words, space regarded as a plenum of lines is four-fold. The same result follows from the consideration that the lines in a plane, and the planes through a point are each two-fold.

Again, if we take a sphere as our element we can through any point as a center draw a singly infinite number of spheres, but the number of such centers is triply infinite; hence space as a plenum of spheres is four-fold. And, generally, space as a plenum of surfaces has a manifoldness equal to the number of constants required to determine the surface. Although it would be beyond our present purpose to attempt to pursue the subject further, it should not pass unnoticed that the identity in the four-fold character of space, as derived on the one hand from a system of straight lines, and on the other from a system of spheres, is intimately connected with the principles established by Sophus Lie in his researches on the correlation of these figures. If we take a circle as our element we can around any point in a plane as a center draw a singly infinite system of circles; but the number of such centers in a plane is doubly infinite; hence the circles in a plane form a three-fold system, and as the planes in space form a three-fold system, it follows that space as a plenum of circles is six-fold. Again, if we take a circle as our element, we may regard it as a section either of a sphere, or of a right cone—given except in position—by a plane perpendicular to the axis. In the former case the position of the center is three-fold; the directions of the plane, like that of a pencil of lines perpendicular thereto, two-fold; and the radius of the sphere one-fold; six-fold in all. In the latter case, the position of the vertex is three-fold; the direction of the axis two-fold; and the distance of the plane of section one-fold; six-fold in all, as before. Hence space as a plenum of circles is six-fold. Similarly, if we take a conic as our element we may regard it as a section of a right cone—given except in position—by a plane. If the nature of the conic be defined, the plane of section will be inclined at a fixed angle to the axis; otherwise it will be free to take any inclination whatever. This being so, the position of the vertex will be three-fold; the direction of the axis two-fold; the distance of the plane of section from the vertex one-fold; and the direction of that plane one-fold if the conic be defined, two-fold if it be not defined. Hence, space as a plenum of definite conics will be seven-fold, as a plenum of conics in general eight-fold. And so on for curves of higher degrees. This is, in fact, the whole story and mystery of manifold space. It is not seriously regarded as a reality in the same sense as ordinary space; it is a mode of representation, or a method which, having served its purpose, vanishes from the scene. Like a rainbow, if we try to grasp it, it eludes our very touch; but like a rainbow, it arises out of real conditions of known and tangible quantities, and if rightly apprehended it is a true and valuable expression of natural laws, and serves a definite purpose in the science of which it forms a part.

The third method proposed for special remark is that which has been termed Non-Euclidean Geometry; and the train of reasoning which has led to it may be described in general terms as follows: some of the properties of space which on account of their simplicity, theoretical as well as practical, have, in constructing the ordinary system of geometry, been considered as fundamental, are now seen to be particular cases of more general properties. Thus a plane surface, and a straight line, may be regarded as special instances of surfaces and lines whose curvature is everywhere uniform or constant. And it is perhaps not difficult to see that, when the special notions of flatness and straightness are abandoned, many properties of geometrical figures which we are in the habit of regarding as fundamental will undergo profound modification. Thus a plane may be considered as a special case of the sphere, viz., the limit to which a sphere approaches when its radius is increased without limit. But even this consideration trenches upon an elementary proposition relating to one of the simplest of geometrical figures. In plane triangles the interior angles are together equal to two right angles; but in triangles traced on the surface of a sphere this proposition does not hold good. To this, other instances might be added.

It has often been asked whether modern research in the field of pure mathematics has not so completely outstripped its physical applications as to be practically useless; whether the analyst and the geometer might not now, and for a long time to come, fairly say,

"*Hic artem remumque repono*," and turn his attention to mechanics and to physics. That the pure has outstripped the applied is largely true; but that the former is on that account useless is far from true. Its utility often crops up at unexpected points; witness the aids to classification of physical quantities, furnished by the ideas—of Scalar and Vector—involved in the calculus of Quaternions; or the advantages which have accrued to physical astronomy from Lagrange's equations, and from Hamilton's principle of varying action; on the value of complex quantities, and the properties of general integrals, and of general theorems on integration for the theories of electricity and magnetism. The utility of such researches can in no case be discounted, or even imagined beforehand; who, for instance, would have supposed that the calculus of forms or the theory of substitutions would have thrown much light upon ordinary equations; or that abelian functions and hyperelliptic transcendents would have told us anything about the properties of curves; or that the calculus of operations would have helped us in any way towards the figure of the earth? But upon such technical points I must not dwell. If, however, as I hope, it has been sufficiently shown that any of these more extended ideas enable us to combine together, and to deal with as one, properties and processes which from the ordinary point of view present marked distinctions, then they will have justified their own existence; and in using them we shall not have been walking in a vain shadow, nor disquieting our brains in vain. These extensions of mathematical ideas would, however, be overwhelming, if they were not compensated by some simplifications in the processes actually employed. Of these aids to calculation I will mention only two, viz., symmetry of form, and mechanical appliances; or, say, mathematics as a fine art, and mathematics as a handicraft. And first, as to symmetry of form. There are many passages of algebra in which long processes of calculation at the outset seem unavoidable. Results are often obtained in the first instance through a tangled maze of formulæ, where at best we can just make sure of our progress step by step, without any general survey of the path which we have traversed, and still less of that which we have to pursue. But almost within our own generation a new method has been devised to clear this entanglement. More correctly speaking, the method is not new, for it is inherent in the processes of algebra itself, and instances of it, unnoticed perhaps or disregarded, are to be found cropping up throughout nearly all mathematical treatises. By Lagrange, and to some extent also by Gauss, among the older writers, the method of which I am speaking was recognized as a principle; but beside these, perhaps, no others can be named until a period within our own recollection. The method consists in symmetry of expression. In algebraical formulæ combinations of the quantities entering therein occur and recur; and by a suitable choice of these quantities the various combinations may be rendered symmetrical, and reduced to a few well-known types. This having been done, and one such combination having been calculated, the remainder, together with many of their results, can often be written down at once, without further calculations, by simple permutations of the letters. Symmetrical expressions, moreover, save as much time and trouble in reading as in writing. Instead of wading laboriously through a series of expressions which, although successively dependent, bear no outward resemblance to one another, we may read off symmetrical formulæ, of almost any length, at a glance. A page of such formulæ becomes a picture; known forms are seen in definite groupings; their relative positions, or perspective as it may be called, their very light and shadow, convey their meaning almost as much through the artistic faculty as through any conscious ratiocinative process. Few principles have been more suggestive of extended ideas or of new views and relations than that of which I am now speaking. In order to pass from questions concerning plane figures to those which appertain to space, from conditions having few degrees of freedom to others which have many—in a word, from more restricted to less restricted problems—we have in many cases merely to add lines and columns to our array of letters or symbols already formed, and then read off pictorially the

extended theorems. Next as to mechanical appliances. Mr. Babbage, when speaking of the difficulty of insuring accuracy in the long numerical calculations of theoretical astronomy, remarked, that the science which in itself is the most accurate and certain of all, had through those difficulties become inaccurate and uncertain in some of its results. And it was doubtless some such consideration as this, coupled with his dislike of employing skilled labor where unskilled would suffice, which led him to the invention of his calculating machines. The idea of substituting mechanical for intellectual power has not lain dormant; for beside the arithmetical machines whose name is legion—from Napier's Bones, Earl Stanhope's calculator, to Schultz and Thomas's machines now in actual use—an invention has lately been designed for even a more difficult task. Prof. James Thomson has in fact recently constructed a machine which, by means of the mere friction of a disc, a cylinder, and a ball, is capable of effecting a variety of the complicated calculations which occur in the highest application of mathematics to physical problems. By its aid it seems that an unskilled laborer may, in a given time, perform the work of ten skilled arithmeticians. The machine is applicable alike to the calculation of tidal, of magnetic, of meteorological, and perhaps also of all other periodic phenomena. It will solve differential equations of the second and perhaps of even higher orders. And through the same invention the problem of finding the free motions of any number of mutually attracting particles, unrestricted by any of the approximate suppositions required in the treatment of the lunar and planetary theories, is reduced to the simple process of turning a handle.

Coterminous with space and coeval with time is the kingdom of mathematics; within this range her dominion is surpreme; otherwise than according to her order nothing can exist; in contradiction to her laws nothing takes place. On her mysterious scroll is to be found written for those who can read it that which has been, that which is, and that which is to come. Everything material which is the subject of knowledge has number, order, or position; and these are her first outlines for a sketch of the universe. If our more feeble hands cannot follow out the details, still her part has been drawn with an unerring pen, and her work cannot be gainsayed. So wide is the range of mathematical science, so indefinitely may it extend beyond our actual powers of manipulation, that at some moments we are inclined to fall down with even more than reverence before her majestic presence. But so strictly limited are her promises and powers, about so much that we might wish to know does she offer no information whatever, that at other moments we are fain to call her results but a vain thing, and to reject them as a stone when we had asked for bread. If one aspect of the subject encourages our hopes, so does the other tend to chasten our desires; and he is perhaps the wisest and, in the long run, the happiest among his fellows who has learnt not only this science, but also the larger lesson which it indirectly teaches, namely, to temper our aspirations to that which is possible, to moderate our desires to that which is attainable, to restrict our hopes to that of which accomplishment, if not immediately practicable, is at least distinctly within the range of conception. That which at present is beyond our ken may, at some period and in some manner as yet unknown to us fall within our grasp; but our science teaches us, while ever yearning with Goethe for "Light, more light," to concentrate our attention upon that of which our powers are capable, and contentedly to leave for future experience the solution of problems to which we can at present say neither yea nor nay. It is within the region thus indicated that knowledge in the true sense of the word is to be sought. Other modes of influence there are in society and in individual life, other forms of energy besides that of intellect. There is the potential energy of sympathy, the actual energy of work; there are the vicissitudes of life, the diversity of circumstance, health and disease, and all the perplexing issues, whether for good or for evil, of impulse and of passion. But although the book of life cannot at present be read by the light of science alone, nor the wayfarers be satisfied by the few loaves of knowledge now in our hands; yet it would be difficult to over-

state the almost miraculous increase which may be produced by a liberal distribution of what we already have, and by a restriction of our cravings within the limits of possibility. In proportion as method is better than impulse, deliberate purpose than erratic action, the clear glow of sunshine than irregular reflection, and definite utterances than an uncertain sound; in proportion as knowledge is better than surmise, proof than opinion; in that proportion will the mathematician value a discrimination between the certain and the uncertain, and a just estimate of the issues which depend upon one motive power or the other. While on the one hand he accords to his neighbors full liberty to regard the unknown in whatever way they are led by the noblest powers that they possess; so on the other he claims an equal right to draw a clear line of demarcation between that which is a matter of knowledge, and that which is at all events something else, and to treat the one category as fairly claiming our assent, the other as open to further evidence.

And yet, when he sees around him those whose aspirations are so fair, whose impulses so strong, whose receptive faculties so sensitive, as to give objective reality to what is often but a reflex from themselves, or a projected image of their own experience, he will be willing to admit that there are influences which he cannot as yet either fathom or measure, but whose operation he must recognize among the facts of our existence.

THE MAGNETIC NEEDLE—THE CAUSE OF ITS SECULAR VARIATIONS.

By THOMAS JOB, Utah.

VARIATION IN THE DECLINATION.

Nearly three centuries ago philosophers observed that the magnetic needle did not always lie in the same direct line, even on the same meridian, but that in the northern hemisphere its north pole has a secular movement around a certain point or pole, not far from the pole of the world; it points sometimes to the east and at other times to the west of the same meridian, performing the northern half of a revolution in 318 years. "The Earth a Great Magnet" (Prof. A. M. Mayer.) A very remarkable phenomenon is observed—it follows the law of a swinging pendulum—retarding in velocity from the meridian of the station to its easterly or westerly tropic.

In the year 1622 the declination of the needle at London was 6° to the east of the geographical meridian. In 1660 the needle pointed due north and south, thus varying 6° in 38 years, while vibrating near the meridian of the place. In 1818 the needle varied, according to Prof. Watts, 24° 36′ to the west, and in 1865, 21° 6′ west; that is, varying only 3° 35′ in 45 years, when moving near its westerly tropic.

The cause of this secular change in the declination of the compass needle has been a theme of investigation with philosophers ever since its discovery, and in no time more ardently than in our day; but no satisfaction has yet been given to scientists. All that has been accomplished by observers is to show that the north magnetic pole is now vibrating from west to east, and at London, approaching the meridian.

It has been further observed that the magnetic needle, in its grand secular swing, makes some minor vibrations and deflections, some of which appear to follow regular laws and be periodical; their physical cause is found to be dependent on the sun as primary mover; others are evidently irregular changes, disturbing more or less the periodical variations.

The most remarkable of the periodical variations is what is called the daily vibration; it manifests its relation to the sun by following him in his apparent daily motion around the earth, in the northern hemisphere, and during the hours of the day from east to west, and from west to east in the hours of the

night; but the contrary way in the southern hemisphere.

These easterly and westerly variations in all parts of the globe where observations have been made, are obviously governed by distinct laws. The westerly deflections in the British Isles, as represented by the self-moving records at Kew, as Dr. Noades observes, have their chief prevalence from 5 A. M. to 5 P. M., and the easterly deflections during the remaining hours, causing the needle to return to its former position by 5 o'clock the next morning.

The extent of the daily oscillation of the needle is small, and also variable. Its mean value at Philadelphia, as observed by Dr. Bache, is 7.5′. The mean extent of the vibration at any station varies with the daily changes in the sun's declination, and so having semi-annual inequality, being deflected towards the east, and therefore with a negative sign, or less than unity, when the sun is north of the equator; but toward the west, and consequently more than the mean, when the sun is south of the equator.

The annual variation, independent of the daily, is a very small quantity, amounting, in the British Isles, to only about 59.56 sec., as given by General Sabine, being 28.95 sec., from March 21st to the 21st of September, with the signs minus and plus 29.9 sec., during the remaining six months. It affects in like manner both the northern and southern needles.

The daily variation of the needle also varies with variation in the latitude of the observer; reckoning from a certain, and seemingly fixed line, termed the *magnetic equator*. In fact the needle, in its daily swing, does not play backward and forward, pendulum-like, across the meridian of a station, but virtually its north pole revolves with the sun around the earth—toward the west in the northmen's day, and toward the east in the day of the southern hemisphere. So in the southern hemisphere the motion of the needle appears to be reversed, towards the east in the day time and towards the west in the night.

The case is also the same with the *secular vibration;* in the southern hemisphere the needle appears to vibrate in the opposite direction to what it does in the northern.

Only that part of the daily motion in which the needle swings westward belongs to the northern hemisphere; the same with its corresponding secular vibration; and that part below the earth, where the needle moves from west to east, represents the secular swing in the southern hemisphere; even as it is day there when it is night with us, and the positive pole of the needle follows the sun.

Proper investigation will show that this daily vibration is the fundamental cause of both the annular and the secular variations of the magnetic needle.

There are in our common year 366 siderial days, but only about 365¼ solar days, that is, while the earth rotates 366 times on its axis it revolves once in an orbit around the sun in the same direction,—from west to east,—and thus we have only 365¼ days out of 366 earth rotations; so the sun appears as if to step backwards—toward the west—from the earth, to the amount of one day's motion in a year. Thus he continues to recede westward from the earth—in the northern hemisphere, by the same space, year after year, till he returns again to the starting point in the orbit, where the earth will meet him, after gaining on him one whole revolution. The pole of the magnetic needle, which, as shown above, respects the sun in all its movements, also recedes westwards—in the northern hemisphere—from the meridian of the place by the space of one day's westward swing in a solar year. From this point of view, one can clearly discern, that our theory admit, that the magnetic equator of a planet lies direct in the plane of the equator of the sun, hence, in the case of our earth, it inclines to the ecliptic, according to Dr. Herschel, by the angle of 7° 20′. But the axis of the ecliptic inclines to that of the earth's equator by the angle of 23° 27′ nearly, from which take the angle 7° 20′, and there remains 16° 7′ for the inclination of the earth's equator to that of the sun, which is the very degree given by Dr. Mayer as the mean inclination of the magnetic equator to the terrestrial, as found on actual observations.

Now, it is evident that that magnetic meridian which passes through the node,

or point of intersection of these two equators, is at right angles with the magnetic equator, and consequently inclines to the true meridian at that point by the same angle of 16° 7′. When the needle in its secular swing comes to this meridian—which I shall term the *prime*—the rate per year of declination should be of the greatest value, and its tropics, east and west, should decline from it by the same angle of 16° nearly.

Next I shall inquire, as to whether this accords with the observations already made by scientists. The following table gives the declination of the compass needle at London, with the mean rate of its motion as referred to periods of observation between 1580 to 1865, comprising a part of an easterly half, the whole of the westerly, and a part of the next westerly half vibration. (Sir Wm. S. Harris' Rudiments of Magnetism. Dr. Woad's Ed. page 258; also Dr. Lloyd of Dublin).

EASTERLY DECLINATION.

Years of observation......	1580	1622	1660
Declination................	11°5′	6°0′	0°0′
Rate per Year of Declinat.	0°7′	0°8′	0°10

WESTERLY DECLINATION.

Years.	1692	1723	1730	1765	1818	1852	1865
Decl..	6°0′	8°36′	13°0′	20°0′	24°36′	22°30′	20°44′
Rate p. Y.	11′	11.7′	11.5′	0.9′	0.0′	0.5′	0.7′

Here we see that the rate per year of the variation was greatest about 1723, the time the declination at London was 8° 36′, that the tropic was reached in 1818 when the rate per year was zero, and the declination from London 24° 36′ or about 16° from the point where the rate per year was the greatest, or the node of the two equators.

Now, this prime meridian, or that which lies in the plane of the sun's axis, and intersects the two equators at their nodes, must become an important line in terrestrial magnetism, for when the horizontal magnet, on its secular swing, passes over it, it is then at its greatest amplitude, or most distant point from its tropics, its rate per year the swiftest, and the daily vibration of the greatest value; and the nearer a station is to this line on the same magnetic latitude, the greatest in proportion is the visible range of its daily vibration.

And even this is not all. When the dipping needle, in its secular vibration, comes to this line, it is always in one of its tropics. This is, as I shall soon prove, the very line of its apsides.

I have now arrived at my evidence that the magnetic equator of the earth lies in the plane of the equator of the sun, and since the magnetic pole revolves about that of the earth, it is plain, that the magnetic meridian cannot, in all places, and at all times cut the magnetic equator at right angles; it can only do so at that place called the nodes of the two equators.

Sir Wm. Snow Harris, in the volume just alluded to, observes that the oscillation of the needle across the true meridian is variable, that the limit of its angular variation at London is 24° 36′. It seems that he also understood, that the limit is not of that amount at all places, that it is only so at London, and those places under the same meridian. In fact, this angular variation at any station depends on the distance of its meridian from the prime meridian—the difference of its declination at London from the prime meridian is 8° 36′, which added to 16° gives 24° 36′, the observed angular variation of the needle at London, when it arrives at its westerly station where the variation rate per year is zero.

I further discovered, that the extent of the mean yearly vibration at any station is equal to the daily vibration at the time the needle comes to the prime meridian. The rate of the vibration at any station, evidently increases or decreases with the rate per year at which the needle moves in that declination, which is as the square root of the declination itself; both the rate per year, and the extent of the swing is evidently greater in the plane of the prime meridian, even as the magnetic intensity is greater in the plane of the solar axis.

From what has been said, it is evident that the magnetic axis only advances in its orbit during the time the needle vibrates westward; for though the earth continues to move regularly in its orbit, yet, while the needle moves to the east the magnetic axis does not advance on the earth's surface, for it only advances westwards, as before shown, and as the needle, which is always coincident with the axis of the sun, only moves westward for about half of the time, the magnetic

axis, in the mean, only advances westward about 30′ per day, as the earth advances nearly a degree a day in the zodiac. So, all other causes eliminated, the whole daily advance of the needle would only amount to that arc. But there are other phenomena that should be taken into consideration. The declination of the needle, as said before, changes with the sun's declination, and also with the motion of the earth in its orbit. Dr. Bache in his "Magnetic Discussions," page 10, has this remarkable expression: "The annular vibration depends on the earth's position in its orbit. The diurnal variation being subject to an inequality depending on the sun's declination. The diurnal range is greater when the sun has north declination, and smaller when south declination; the phenomenon passing from one state to the other, about the time of the equinoxes." Also, the diurnal range apparently increases as the needle in its secular variation approaches the prime meridian. Mr. Graham, the discoverer of the diurnal variation, who, happily made this discovery in 1723, about the time when the needle was crossing this line, as seen in the table above, found the daily variation to range 30′, the amount we found above as the mean range in the northern hemisphere. Dr. Bache adds, page 12: "At, (and before and after) the principal maximum (of the annular variation) between six and seven in the morning, the annular vibration causes the north end of the needle to be deflected to the east in summer, and to the west in winter; at one p.m. the deflection is to the east in winter and to the west in summer. The range of the diurnal motion is thus increased in summer, and diminished in winter; the magnet being deflected in summer more to the east in the morning hours, and more to the west in the afternoon hours, or having greater elongation than it would have if the sun moved in the equator. In winter the converse is the case." He also says, page 13, in reference to the annular variation, that Gen. Sabine expresses himself as follows: "Thus, in each hemisphere, the annual deflections—those that change with the declination of the sun—concur with those of the mean annular variation for half the year, and consequently augment them, and oppose, and diminish them in the other half. At the magnetic equator, there is no mean diurnal variation; but in each half year the alternate phases of the sun's annual inequality constitute a diurnal variation, of which the range in each day is about 3′ or 4′, taking place every day in the year except about the equinoxes; the march of the diurnal variation being from the east in the forenoon to the west in the afternoon, when the sun has north declination, and the reverse when south declination." According to the same authority (Gen. Sabine), the annular variation is the same in both hemispheres, the north end of the magnet being deflected to the east in the forenoon, the sun having north declination, while in the diurnal variation, the north end of the magnet, at that time of the day, is deflected to the east in the northern hemisphere. In other words, in regard to direction, the law of the annular variation is the same, and that of the diurnal the opposite, in passing from the northern to the southern hemispheres.

Now, since I showed that the diurnal variation is of the same extent as the annular steps of the secular variation, we only gain half a day's motion of the sun in a whole year; for as the direction of the needle's motion in the night is to us in opposite direction to what it is in the day, so the secular motion in the southern hemisphere is contrary to that in the northern hemisphere, so as to cause the yearly variation to help the diurnal, and so augment the secular in the northern to the amount of nearly 4′, as showed before, which is the range of the yearly variation about the magnetic equator; so the secular swing of the needle in the northern hemisphere becomes 34′ per year nearly. Now, 180°—the whole swing from tropic to tropic—divided by $34=318$ years, the secular period of a whole vibration in the northern hemisphere, which is the very period given by Dr. A. M. Mayer in that celebrated lecture, "The Earth a Great Magnet," alluded to before. As to the reason why the secular swing of the needle appears to follow the law of a pendulum swinging about the center of gravity of the earth, is, that while the needle describes those parts of its orbit about the eastern and western tropics, its motion is nearly

in the direction of the line of our vision. As the needle advances in its orbit, the course of its swing makes a greater angle with that line, so as to appear to move swifter and swifter, until it arrives at the meridian of the station; where its sweep is at right angles to our vision line, and its velocity appears the greatest of all.

OF THE SECULAR MOVEMENT OF THE MAGNETIC NODES.

This motion may be termed "the most grand magnetic vibration." Since the magnetic needle in all of its movements respects the apparent motions of the sun, I thought it worthy of remark, that, from the phenomenon termed "the precession of the equinoxes," the nodes of the sun, or points where his path in the heavens cut the equinoctial, recede westward through the constellations of the zodiac, at the rate of about 50 sec. a year, which in connection with the eastward movement of the line of the apsides—12 sec. a year—performs a grand revolution in about 21,000 years; as the axis of the sun is thus carried westward around the earth, the magnetic nodes, or points where the sun's equator cuts the terrestrial, should also move at the same rate and in the same direction on the terrestrial equator, and so describe the same grand revolution from east to west in that vast period. And, not more strange than true, philosophers, long ago, observed this to be actually the case, though they could not account for it.

Sir Wm. Snow Harris, in the volume before alluded to, page 266, has the following remarkable expression: "By a careful analysis of the observations recorded at long intervals of time, the nodes, or points of intersection of the magnetic and terrestrial equators, have a slow westerly movement."

OF THE SECULAR VARIATION IN THE INCLINATION, OR DIP OF THE MAGNETIC NEEDLE.

From what has been explained with regard to the declination of the magnetic needle, it is evident that when such a needle is set to move freely, it always rests with its axis in the plane of the axis of the sun; which, as before demonstrated, revolves around the axis of the earth, in an orbit that declines from it by an angle of about 16°.

Now, if the earth were to revolve in the plane of the sun's equator, or that of any of its parallels, the dip of the needle would be always the same, in the same terrestrial latitude. But since the earth's orbit inclines to the sun's equator, and so the earth appears sometimes below, and sometimes above that plane, the magnetic pole of the earth, which is in juxtaposition to the pole of the sun, must appear to move alternately up and down on our meridians, according to what part of the orbit the sun appears to describe. And it is worthy of remark, that this phenomenon had long ago been observed by scientists to really exist, and termed "the secular variation of the dip of the needle." Though this phenomenon had been observed, the rate of its motion from time to time being watched, and its effect on the magnetic force and the movements of the isoclinal lines of the earth accurately determined by scientists, yet the extent of its vibration, the length of its period and the place of its tropics, had not been discovered by them.

Gen. Sabine observes, that it had been expected by many that the secular period of the dip's variation, which was then decreasing, would synchronize with that of the declination, and that the dipping needle would also come to its tropic in 1818; and that the dip would commence to augment from that period. But the philosophers had been disappointed in their expectation; the needle is still descending—the dip is still decreasing in the British Isles.

Now, the true amount of the variation of the needle from its mean at any station, is the same as the inclination of the axis of the ecliptic to that of the sun, which had been given before as 7° 20′. And since the needle always rests with its length in the plane of the solar axis, one might infer that its period is the same as that of the secular variation of the declination needle.

There is, to appearance, a vast disagreement between the periods of these two phenomena, but, by my theory, they should correspond; and, indeed, if we scrutinize their movement, there is the utmost correspondence—they exactly synchronize. The mistake remained, in

taking the meridian of London, for the goal to be sought for by the needle, instead of the prime meridian, or axis that passes through the intersection of the two equators.

The last period of the maximum of the inclination, or when the dipping needle came to its upper station, occurred in 1723, when the dip was 74° 42′ at London; this I call the upper transit of the needle over the prime meridian, where the dip is the greatest, from where the needle commences to fall, and the inclination diminishes in value for the space of 7° 20′. Now, if we consult the table given elsewhere, we will find that this year, (1723), was the very year the declination needle came to a coincidence with the prime meridian, where its declination to the true meridian was 16° 7′, and where the rate per year of its secular movement was the greatest of all.

By 1840, according to the observations made at Kew, the dip was 69° 12′, the difference in 116.7 years being 5° 28′ nearly, equivalent to an uniform diminution of 2′ 8 sec. annually, and Gen. Sabine observes that the rate of the diminution of the dip in London had not materially changed for the last 150 years.

The grand vibration of the declination needle, according to Dr. Mayer, is made in 318 years, half of which is 159 years, this multiply by 2.8=445′, or 7° 25′, the arc through which the needle falls, which is nearly equal to the given inclination of the ecliptic to the solar equator, 7° 20′. And I think the former is the most true measure of the latter, for it is evident, even if the latter was formerly correct, that as the inclination of the ecliptic to the earth's equator diminishes, its inclination to the sun's equator must increase by the same amount. Thus we see, that the secular period of the dipping needle is also the period of the declination needle; they were together on the prime axis in 1723, and will again meet on the same line in 1882, for 1723+159=1882, when the dip will begin to increase again.

I may here remark that to the east of the prime meridian, both the declination and the inclination of the needle increase in value till the needle arrives at its upper transit, whence, in describing the western hemisphere, they both decrease again.

One thing I have taken for granted in the above discussion—that the dip of the magnetic needle is double that of its magnetic latitude at any station—and as some modern scientists dispute the truth of this principle, and the propriety of its application to terrestrial magnetism, I shall make a few remarks thereon.

A few years ago, I independently discovered that the angular dip of the magnetic needle is double that of the magnetic latitude at the same station; but have since found that Mr. Kroft, of St. Petersburg, had long before deduced this law from his observation, and that Mr. Barlow, of England, subsequently arrived at a similar deduction by experimenting on a magnetic sphere of soft iron; that Biot endorsed it, and has given a formula for the inclination. I am pleased to yield the honor of the discovery to these wise men. But the explanation of the cause of this phenomenon I have not as yet met with.

It is represented in books, that at the magnetic pole the dip of the needle is 90,° and so it is to the horizon at that point; but not so in comparison to the horizontal needle at the magnetic equator. For, the earth being a globe, the position of the needle at the pole is "parallel" to that on the equator, its north pole points in the opposite direction, or it declines from the latter position by the arc of 180,° or twice 90° the greatest latitude.

It is a well known principle in optics, that, when a light is reflected from a rotating mirror, that the angle of reflection of a ray is double that of the rotating mirror, that is, if the mirror be made to rotate through 45° the reflected beam would pass through 90°.

If we now suppose the mirror to be a globe like our earth, it is evident that moving the beam around the globe from the equator to the pole would produce the same effect as causing the plane mirror to rotate. The same law is evidently observed by the dipping needle, in swinging its tail around the heavens, as it is carried in a free position from the magnetic equator to its poles.

The Secretary of State for India desires that the municipality of Bombay would urge the Government to carry out a system of drainage, as that would remove one source of ill-health and disease.

THE PROGRAMME OF THE STUDIES OF THE ARCHITECT AND OF THE CIVIL ENGINEER.

From "The Builder."

The programme of the International Congress on Civil Engineering, lately reproduced in our columns, is not one that we can regard with entire satisfaction. As to its merit—as a compendious catalogue of the exhibits or contributions of any kind brought before the Congress, we have nothing to say. But we are entitled to expect that a document of this nature should form a sort of skeleton outline of the science of engineering. As such, especially when drawn up with the lucidity of phrase and systematic order which for the most part characterize French scientific works, such a paper might form a contribution of no little value to the science of higher education. As it is, however, the gaps and blanks are almost as conspicuous as the features illustrated. Thus, there is a head, "*Télégraphes pneumatiques*," but not a word as to the electric telegraph, or those wonderful methods now in process of daily improvement, by means of which the electric fluid is employed for the purpose of giving sonorous signals at a distance; or, in the words of Mr. Spottiswoode, electricity is converted into sound. Again, there is a heading "*Inondations: Moyens à leur opposer*," but not a word as to the first essential for carrying out any of these methods, the hydraulic survey of the district liable to the floods. Indeed, the whole question of survey, the very ground-work and basis of civil engineering, is omitted from the French programme.

We hold that a positive injury is inflicted on scientific education by the setting forth of partial details as if they constituted the whole of any branch of study. The tendency of the age is to run into detail. The division of labor is a means of acquiring intellectual, as well as physical wealth. But the danger of losing sight of the whole in elaborate detail of the parts is great and urgent. Unless the general form of a science or art be kept clearly before the attention of its students, they not only sink into mere specialists, but work in their special branches of study with less advantage than would be the case were their ideas enlarged, so as to appreciate the relation of their particular work to the general advance of the study of which it is an integral part.

We have been very much struck, within the past few weeks, with examples of the mode in which this specialisation of attention appears to have cramped and injured the *coup d'œil* of the architect. It is unnecessary to indicate localities, further than to say that we speak of a part of the country where pure air, noble prospects, good roads, and comparative sparseness of population are such as to prevent unusual inducements for the erection of private residences of a high class. Beautiful specimens of old English architecture stud the country, from the cottage and the farm to the baronial or knightly mansion. Men are found to understand these advantages, and to avail themselves of their existence. Money, it is certain, is forthcoming with an unstinted hand. A sort of paradise is open to the architect.

Yet here we find houses rising at costs varying from £1,500 to £15,000, or upwards, the inspection of which, as their plans gradually define themselves in brick, and stone, and mortar, serves to announce the absence of the architect—using the term in its highest sense. It is not that we have to complain of scamping, or of slovenly work. Quite the contrary. The details are often admirable. But the faults that we lament are the want of grasp, of breadth of plan, and of adapting the methods of the builder to the special circumstances of site. Here is a house that we might take as a model in many respects, with the stable-yard crammed—quite unnecessarily—so close to the main entrance as to shut off the garden view, and promise anything but salubrity to the reception-rooms, if the stud be more than a cypher. There we see three or four houses, each, may be, of some pretension to comfort and elegance, stuck so heedlessly in one another's light as to form an ill-adjusted

block, where there might have been a picturesque and self-contained group of residences. In another place we see a road so diverted as to cram one house into an ill-shaped triangular garden, commanded by two roads, while the attempt to obliterate the old road by the simple process of planting, without any reference to the rules of landscape or other gardening, has brought a bit of irredeemable Cockneydom into what was a little while since an elegant and picturesque country road. In another place, where at least from £15,000 to £20,000 must be in course of expenditure, where the site commands a magnificent view, and where the preparations for a terraced garden denote a great freedom from any narrow ideas as to cost, we find, rising in the air, instead of a noble mansion, a heterogeneous collection of rooms. A Gothic archway, that might serve for a church, opens into a little insignificant low vestibule, which entirely destroys the *raison d'être* of the gateway. Where a noble oriel window ought to command a broad and diversified view, a chimney is placed, with a small square glazed aperture, called by courtesy a window, on each side. By the doorway, a shapeless window, which looks like that of a buttery, is intended, by some strange caprice, to light a studio or drawing-room. All the details are admirable. No doubt some good examples may be cited for every mullion, every moulding, perhaps every room. But whole there is none—only a jumble of parts—and of parts that are petty and inappropriate, when the situation demands the simple and the grand.

Now we cannot doubt that an architect who, at the same time has so much and so little of what is required for excellence in his work as the author of this design, must be a sufferer from a want of that comprehensive, systematic, subordinated programme for his work, the want of which we lament in the Paris programme. Given a site of unusual beauty, and far-reaching view, the first duty of the architect should be so to arrange the chief rooms, and especially the windows, of the house as to take this view as much as possible within—to make it an unrivalled furniture of the reception apartments. Secondly, we might suggest, the idea of making the edifice a consistent and graceful pile of buildings, as forming part of the view from neighboring heights, should not have been forgotten. But to make use of such an opportunity for the sole purpose of reproducing Elizabethan mullions, thirteenth-century arch and mouldings, and quaint little windows out of which no one can look, is,—in our view of the case,—not only to waste money, but to sacrifice reputation.

With this view we will attempt to sketch out something of a rough programme of engineering study. Our work must be, necessarily, tentative and provisional. But those who may mend it, not by the criticism or the addition of mere details, but by giving a greater roundness, completeness, and system to the whole, will deserve well of their professional brethren and pupils.

The business of the engineer, then (to return to the Paris programme) contains three main divisions or provinces. These are (1) survey; (2) physical engineering; and (3) mechanical engineering. The head of special or unclassed studies may be added, provisionally, to include those pursuits which are in the course of rapid development, or which have not as yet been sufficiently advanced to be relegated to their appointed stations in the completed system of scientific order.

Survey is the basis of the whole science of engineering. It is either general or special. It ranges from geodesic operations of the first magnitude to the careful exclusion of a bit of sappy timber from a bridge or a door. The antiquity of the work of the surveyor has very recently been illustrated in an unexpected manner. An Assyrian tablet, in baked clay, has just been translated for our pages. It is a deed of sale of a plot of ground, and a plan of the ground in question is attached. This most ancient land survey is more than 2,000 years old. Had the plans of Rome, which were engraved on marble, been copied in terra-cotta, we might at this moment have a more accurate knowledge of the ancient topography of the Eternal City than we have of London in the time of the Conqueror. But it was not till the end of the last century that a trigonometrical survey was generally allowed to be the only accurate basis for mapping a country. General Roy began the trig-

onometrical survey of Great Britain by measuring his famous base on Hounslow Heath in 1784. In 1802, Major Lambton commenced the mathematical and geographical survey of India by measuring a base-line near Madras. Sir George Everest extended Lambton's "great arc series" across the plains of the Ganges, to the foot of the Himalayas; and when the vast peninsula had been covered with a gridiron of triangles, and a second base was measured in the valley of the Debra Dur, the difference between the computed and the measured length was only 7 inches. The height of the loftiest of the Himalayan peaks, named, in fit tribute to the great surveyor, Mount Everest, was determined by measurements of angles by the great theodolite as 29,002 feet above the sea.

Survey, then, forms the first part of the programme of the study of the engineer. It includes geodesic survey proper, or triangulation, with astronomical determinations of salient points; geographical and topographical delineation; orography, or the contours of the country; geological survey; hydrological survey; and hydrography, or preparation of charts of coasts and estuaries, including soundings and determination of tides and currents. Land survey is an important detail, subordinate to topographical delineation. The shading of hills and delineation of water-sheds, with the preparation of physical maps, ranks under the head of orography. The survey of buildings, and of quarries, mines, forests, and other sources of materials for the engineer and the builder, carries the duties of the surveyor to their limit of detail. We have not spoken of the pioneer surveyor, whose duty, though important, is only provisional.

Each branch of physical engineering is properly based on a branch of survey. The first call upon the engineer is for the establishment of communications. For this purpose, when the first stage of rough work is passed, the orographical and topographical surveys furnish the data. Communications at present are divided into national and international, or exterior and interior; divisions which partly, though not wholly, correspond with that of communication by land or by water. For the former, the engineer has to study the formation of roads, pavements, tramways, and railways; for the latter, he has to provide ports and harbors, to cut canals, and to systematize rivers.

The provision of internal waterways is closely connected with other branches of hydraulic engineering, based on hydraulic survey. Among them are drainage and irrigation—a study which requires for its completion the survey and regulation of forests and plantations. In the second place ranks the provision for the water-supply of urban districts, and, generally, of the population of the country. Inseparable from the water-supply question is that of sewerage, including the disinfection of its effluent water. Agricultural engineering must be considered in detail under a separate head, but is deeply affected by the system adopted for irrigation and drainage. The details of earthwork, masonry, timber, ironwork, and other element of construction, may be grouped together by the writer or lecturer, but will be studied practically by the pupil as they are carried out on the different public works of which the main characters are above indicated.

Mining, quarrying, coal-mining, well-sinking and boring, form a separate branch of study. It is related, on the one hand, to forestry and woodcutting; and, on the other hand, to metallurgy, smelting, and the making of iron and steel. The civil here comes into immediate contact with the mechanical engineer, whose cradle and school are found in the vast establishments which add forges to furnaces, and not only cast, roll, hammer, and forge, but also, turn, bore, and plane vast and complex objects of metal.

As the physical engineer gives his hand to the mechanical, so does the latter need much of the knowledge of the chemist. The study of heat has been usually regarded as a part of physics; that is to say, of that *remanet* of natural science which has not yet been portioned out under the name of a special study. But while, on the one hand, the study of heat, as far as its production and its metallurgic effect are concerned, is a part of industrial chemistry, the determination of the relation of heat to motion, which is one of the grandest strides of recent science, renders the

study of caloric a distinct part of mechanics. The English thermal unit—called after the name of its discoverer, Joule's equivalent—determines the equality of the energy required either to raise 772 lbs. for a foot, or to raise the temperature of 1 lb. of water by one degree of Fahrenheit's scale. This elevation of temperature in a pound of water can be produced by the consumption of half a grain of carbon. If water descends freely through a distance of 772 feet, it acquires from gravity a velocity of 223 feet per second; and if suddenly brought to rest when moving at this velocity, would be violently agitated, and raised one degree Fahrenheit in its temperature. So intimately connected are chemical, thermic, and mechanical phenomena. The study of mechanical engineering may be described as regarding, in the first instance, the application of natural sources of motion. These are water, wind, and animal power, to which the ingenious labors of Capt. John Ericsson have enabled the engineer to add the radiant heat of the sun.

The readiness with which the force of gravity can be utilized by falling water was perhaps one of the first discoveries in mechanics. The origin of the water-wheel is lost in the remoteness of antiquity. Still more ancient, no doubt, were the simplest contrivances employed, and to this day in use in India, for raising water for the purpose of irrigation. The construction of water-wheels—over-shot, breast, or under-shot—of turbines, or of any other apparatus for utilizing the mechanical force of a fall or current of water, is falling into neglect in our densely-peopled country. Certainty in command of power is even more essential to the owner of a large mill or factory than economy; and steam is displacing water as a prime motor for that reason. This is not, however, the case in America, in Italy, or in some other localities, where the water-mill is still a very important care of the engineer. In Great Britain, the disuse of water as a prime mover is likely to be fully made up for by its constantly increasing use as a transmitter of motion. The accumulator principle is one likely to exercise very wide development. Hydraulic rams, presses, gun-carriages, and second motors of all kinds are daily in course of new application. And the pump, with all its numerous applications, may be studied under this branch of engineering.

The service of wind as a motor power is falling still more rapidly into disuse than that of water. Long lines of windmills may still be seen pumping night and day, whenever there is a breath of wind stirring, to drain our eastern lowlands and fens; but the windmill is becoming more and more rare as a feature of English landscape. That use of the wind which, half a century ago, was one of the proudest peculiarities of the Englishman, whose insular home made him so often a born sailor, has received a last fatal blow from the opening of the Suez Canal. On the China trade, until that great waterway was opened, the sailing clipper ships competed successfully with steamers; the former passage occupying from 90 to 100 days, as against 75 to 80 days for the latter. On this well-known sea-path the course of the winds could be very clearly anticipated. But ships now run on the Australian line which perform a voyage exceeding 12,000 nautical miles, at an average speed of 11 or 12 knots, and consume only 1,500 or 1,600 tons of coal to drive a weight of 6,000 to 7,000 tons from port to port. Very few sailing vessels of any size are now building; and it is only the yachtsman or the fisherman who is likely long to spread his sails to the wind.

The use of compressed air, as a communicator of motion, however, is advancing together with that of water. The ingenious effort made some thirty-six years ago to avoid the great cost of the self-traction of the locomotive by a pneumatic apparatus, failed, not from mechanical, but from physical causes. As soon as the air in the tube was rarified by the action of the air-pumps, the heat of the earth rushed in, and restored the tension. Thus, the South Devon engines were at work, not only in drawing trains, but in pumping heat out of the earth; and they became almost red-hot in consequence. The use of air as a secondary motor is in its infancy. In some cases, as in mining and tunneling, highly compressed air performs the double function of moving the perforators, and of ventilating and cooling the

works by its escape. It is probable that the employment of compressed air will hereafter receive a great development.

As to the use of animal power, the great object of the engineer at the present day is to dispense with its employment. Among the earliest steps in civilization may be reckoned the attachment of the bullock to the plough; and, much later, that of the horse, not only to the plough, but to the wagon, the boat, and the coach. The entire period comprised in the history of the application of animal power has witnessed an increase in velocity of work or of transport, from about one mile and a third to sixteen miles per hour. The former is the pace of the bullock in the plough; the latter rate of progress, that of a horse, at the fastest trot, was attained by some of the fastest of the English coaches forty years ago. One great disadvantage of animal power is that its cost increases rapidly together with the speed attained. It is not the work done which is the limit of expense; but the wear and tear of the animal tissues. Each creature has its natural pace, or rate of movement; and the most rapidly moving are also the lightest animals, and those least adapted for performing mechanical work. With machinery the reverse is the case. Speed, in machines, is a great element of cheapness. A machine driven twice as fast as another may do twice as much work in the same time; and although the consumption of fuel is proportioned to the work done, much of the other expense will be proportioned to the time occupied in doing it, so that the financial saving becomes considerable. Indeed, if experiments described in the *American Journal of Science and Arts* may be relied on, certain kinds of friction, such as that of journals, decrease with an increase of speed in the revolution of the machinery; a speed of surface revolution of 1 foot per minute giving 15 as a co-efficient of friction, and a speed of 100 feet per minute giving a co-efficient of only five. This diminution of cost accompanying increase of speed is an element which tends to the entire displacement of animal by mechanical moving power. It substitutes the steam-engine, or the caloric-engine, for the bullock or the horse, as the slave of man. Little by little it will extinguish the laborer, or the uninstructed man who derives his pay from the sheer exercise of muscular strength. Not a year passes without the substitution of mechanical power for human labor in some new field. The revolution thus in progress is one of more moment than any that the world has yet witnessed. Very long was it stoutly resisted—and resisted by the very men whose position, it may be hoped, will be elevated by the removal of the burden of toil from their shoulders. This fierce opposition has of late slackened, if not ceased, in this country. It is now rather felt to be the case, very often, that necessary work is shirked, or grudgingly performed, than that the laborer insists on his monopoly of toil. We here touch on a question in which the functions of the engineer bring him into contact with the statistician, with the statesman, and with the philanthropist. But while in newly settled countries, and in sparsely peopled districts, human muscles, and the ready service of the bullock, the horse, the ass, and even the llama, may long retain their present importance as prime movers and sources of power, there seems every reason to anticipate that neither water, wind, nor animal power will be employed as prime movers, except under rare and exceptional cases, in the engineering of the future. To one great exception, however, we have by-and-by to allude.

We cannot do justice to the subject without returning to its discussion. But in closing for the present, we cannot omit to express lively satisfaction at the manner in which the appreciation of the importance of exhaustive and systematic programmes is evinced by the first speaker at the meeting of the British Association. The address of the president is one of which every Englishman may feel proud. Mr. Spottiswoode's tacit protest against a professedly positive, but really negative, attempt to draw a hard-and-fast line to what is to be known, will receive the support of every worker in science, as contrasted with the dreamers in philosophy. Professor Ingram, in his apology for political economy, has taken up our own position—"That the study of the economic phenomena of society ought to be systematically combined with that of the

other aspects of social existence; that the excessive tendency to abstraction and to unreal simplification should be checked; that the *a priori* deductive method should be changed for the historical; and that economic laws and deductions from them should be examined, and expressed in less absolute form.

Nor must we omit, in calling attention to the accordance between the views we have long maintained and those now authoritatively put forth at Dublin, to congratulate the president of the Mechanical Sciences Section, Mr. Easton, C.E., on his advocacy of our own proposal, several times urged, for the creation of an administrative department "charged with the duty of collecting and digesting for use all the facts and knowledge necessary for a due, comprehensive, and satisfactory dealing with every river-basin or water-shed area in the United Kingdom."

WATER ENGINES *VS.* AIR ENGINES.

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I.

If we take no account of the heating due to the compression of air, the ratio of the work restored to the work expended, is expressed by

$$E=\frac{1-\frac{1}{n}}{2.303 \log. n},$$

n being the number of atmospheric pressures.

[*Note.*—The deduction of this formula is given by M. Trasenster in a former article, as follows:

Let p=atmospheric pressure per square meter=10333 kilos.

P=pressure of the compressed air

v & V=volumes corresponding to above pressures

$P=np$

$V=nv$

The theoretical work afforded by compressed air is

$$T_r=(P-p)\,v=Pv-pv$$

but as $Pv=pV$ and $V=nv$

we shall have

$$T_r=Pv-pv=p\,(V-v)=pV\,(1-\frac{1}{n})$$

Whatever the pressure therefore to which one cubic meter of air be compressed the work performed by its expansion will always be less than $p\times 1$ or 10333 kilogrammeters. To accomplish this amount of work $\frac{1}{n}$ must become equal to 0, whence n equal to infinity.

The work of compression is expressed by the formula

$$T_d=pV+\text{nep. log. } n$$

and the ratio of work restored to work expended is as above

$$E=\frac{1-\frac{1}{n}}{pV\times 2.303 \log. n}.]$$

If the heat be taken into account the useful results are still lower and the losses augment with the pressures.

If c represent the specific heat of air at constant pressure

& c' represent the specific heat of air at constant volume

$$\frac{c}{c'}=k=1.408$$

If p represent pressure and Q the corresponding volume, then by Mariotte's law, pQ is a constant. Also according to Poisson pQ_k is a constant

Furthermore the coefficient of dilatation of gases by heat being $\frac{1}{273}=\frac{1}{a}$ and absolute zero being $-273°$ we have the known relation

$$\frac{273+T}{273+t}=\left(\frac{P}{p}\right)^{\frac{k-1}{k}}=\left(\frac{Q}{q}\right)^{\frac{-1}{k}}$$

and representing

$$\frac{k-1}{k}=\frac{0.408}{1.408}=0.29 \text{ by } b$$

we may write the above

$$\frac{273+\mathrm{T}}{273+t}=\left(\frac{\mathrm{P}}{p}\right)^{0.29}=\left(\frac{\mathrm{P}}{p}\right)^{b}=n^{b}$$

From this supposing the initial temperature of the air 10° C we deduce the following values for temperatures for the several pressures given

P= 2 atmo.,	T=	73°
P= 3 "	T=	116°
P= 4 "		150°
P= 7 "		236°
P= 10 "		276°
P= 25 "		451°

If compressed air be expanded a lowering of the temperature is the result, the extent of which may be calculated by the same formula, T representing the initial and t the final temperature. If T=10° and the expansion be the result of diminishing the pressure from 3 to 2, the value of t becomes −21.4°. If T be 25°, t=−8.1°.

If a volume of air, compressed by 7 atmospheres as at Mont Cenis, and St. Gothard, be expanded to atmospheric pressure, we find by the formula

$$\frac{273+10}{273+t}=(7)^{0.29}$$

$$t=-112°.$$

The work absorbed by the compression is, taking the temperatures in account

$$\mathrm{T}_d=\frac{k}{k-1}p\mathrm{Q}\frac{\mathrm{T}-t}{a+t},$$

But we know that

$$\frac{a+\mathrm{T}}{a+t}=\left(\frac{\mathrm{P}}{p}\right)^{\frac{k-1}{k}}=n^{b},$$

From which we get

$$\frac{\mathrm{T}-t}{a+t}=n^{b}-1$$

and as

$$\frac{k}{k-1}=\frac{1}{b}$$

we shall have by substitution

$$\mathrm{T}_d=\frac{1}{b}p\mathrm{Q}\left(n^{b}-1\right).$$

The value of the work restored is

$$\mathrm{T}_r=p\mathrm{Q}\left(1-\frac{1}{n}\right).$$

Consequently we get for the ratio of work restored to work expended

$$\mathrm{E}=\frac{p\mathrm{Q}\left(1-\frac{1}{n}\right)}{p\mathrm{Q}\frac{n^{b}-1}{b}}=\frac{b\left(1-\frac{1}{n}\right)}{n^{b}-1}.$$

and substituting for b its value 0.29

$$\mathrm{E}=\frac{0.29\left(1-\frac{1}{n}\right)}{n^{0.29}-1}$$

The useful effect decreases as the pressure increases, and the more rapidly if we allow the air to heat during compression.

The following table exhibits the difference of useful effects of 1st, the compressed air cooled and, 2d, the compressed air allowed to retain the heat due to compression :

Pressures.	Useful effect. Air cooled.	Useful effect. Heat retained.
2 atm.	0.72	0.65
3 "	0.61	0.52
4 "	0.54	0.44
5 "	0.50	0.39
7 "	0.44	0.31
25 "	0.30	0.18

These figures show that not only is the useful effect diminished as the pressure increases, but that the difference between the performances of these two conditions augments also.

A pressure of seven atmospheres was employed in tunneling the Alps, and the pressure of twenty-five atmospheres has been recommended by M. Mèkarski for tramway engines.

The effect of heating has been largely avoided by the use of water spray as employed by M. M. Colladon, Cornet, and others. Diagrams obtained under such conditions differ but little from those required by Mariotte's law.

It is necessary in order to reduce the loss of work to a minimum to employ the expansive force of the air without so great loss of heat; but the problem presents great difficulties.

M. Cornet who has given much attention to all the practical questions relative

to compressed air, has suggested the use of an injection of water at the temperature of the mines. It has also been proposed to heat the outside of the cylinder, a plan of slight efficiency. Finally it has been proposed to employ, in connection with the compressed air, water heated to a high pressure.

II.

EMPLOYMENT OF WATER AT HIGH PRESSURE.

Compressed air possesses exceptional advantages as a motor for machines working at high velocities in shafts and galleries of mines. Its use, however, involves an expensive equipment, and it is rare that more than a third of the power of the compressing engine is realized in practice. It is, therefore, not an economical method of transmitting force to the depths of mines and tunnels.

Water, by reason of its incompressibility, transmits force without other loss than such as arises from friction. In mines its weight suffices for an initial force, without aid of special devices; but its mass prevents the use of high velocities in water pressure or piston engines. It is necessary, therefore, that in conducting pipes it should move with lower velocities than air or steam.

Notwithstanding the difference in density and mobility of the two fluids, the loss of work due to friction in the pipes can be made as little or less than that from use of air in two ways:

1st. By increasing the diameter of the conducting pipes, and thus reducing the velocity.

2d. By compensating for the diminution of velocity or volume of the water by an increase of the effective pressure without modifying the section of the conduits.

We know that for a circular conduit whose length $=b$, radius $=r$ and delivering a volume Q per second, the velocity

$$V=\frac{Q}{\pi r^2}$$

The *head* which measures the resistances to this motion is calculated by the formula,

$$h=\frac{2c}{r}lV^2 \text{ or } 2\ cl\frac{Q^2}{\pi^2 r^5}$$

The coefficient c is determined by experiment; for gas it is 0.00031; for water it varies between 0.000356 and 0.000385 according to the velocity, 0.00037 may be considered a mean value.

The height being thus determined, the pressure due to this upon a unit of surface is found by multiplying by the weight of a unit of volume. In other words, to calculate the pressure to the square meter it is necessary to multiply the height which measures the friction by the weight of a cubic meter of the fluid.

The weight of a cubic meter of water is 1000 kilograms. A cubic meter of air at 0^o and pressure of $0^m.76$ is $1^k.293$. But the temperature is generally above this and it moreover contains a quantity of watery vapor so that the weight of the meter, under ordinary circumstances, may be taken at $1^k.25$ corresponding to a temperature of 9.4^o. This is $\frac{1}{800}$ of the weight of the same volume of water.

Under a pressure of n atmospheres a cubic meter of air will then weigh $1.25n$ kilograms.

The pressure per square meter for air is

$$h\times 1.25n=\frac{2c}{r}lV^2\times 1.25n=2cl\frac{Q^2}{\pi^2 r^5}\times 1.25n$$

and for water,

$$h'\times 1000=\frac{2c'}{r'}lV'^2\times 1000=2c'l\frac{Q^2}{\pi^2 r'^5}\times 1000.$$

Equating these values;

$$\frac{2clQ^2}{\pi^2 r^5}\times 1.25n=\frac{2c'lQ^2}{\pi^2 r'^5}\times 1000$$

$$\text{or}\quad \frac{c\times 1.25n}{r^5}=\frac{c'1000}{r'^5}$$

$$\text{or}\quad \frac{0.00031\times 1.25n}{r^5}=\frac{0.00037\times 1000}{r'^5}$$

From which we get

$$\frac{r'^5}{r^5}=\frac{1000}{1.25n}\times\frac{37}{31}=\frac{800}{n}\times 1.193.$$

If $n=4$ we find

$$r'^5=r^5\times 200\times 1.193$$

$$\text{or}\quad r'=r\sqrt[5]{238.6}=r\times 2.989$$

Whence we see that it will suffice to triple the radius of the conducting pipe, in order to insure a circulation of water through it by the same effort or moving force as that required for the same vol-

ume of air under a pressure of four atmospheres; a medium $\frac{1}{200}$ of the density of water.

But a better solution of the problem is obtained in another way.

The ratio of the work lost by friction in the pipe, to the work afforded by the water at a pressure of n' atmospheres is

$$\frac{Q'h'1000}{Q'\times 10333n'}=\frac{h'1000}{10333n'}$$

The loss then is a fraction which decreases as n' increases.

In the case of compressed air the ratio of work of friction to effective work is

$$\frac{Qh\times 1.25n}{Q\times 10333(n-1)}=\frac{1.25\,nh}{10333(n-1)}$$

It diminishes with the fraction $\frac{n}{n-1}$ and not with $\frac{1}{n}$ as in the case of water.

But the chief advantage of employing water at high pressure is that we obtain the same effective work as with compressed air, with so much less volume and can, consequently, reduce the velocity in the supply tubes in like proportion.

The work of a volume Q' of water under a pressure of n' atmospheres or $n'p=n'10333$ kil. is expressed by

$$Q'n'p.$$

If we deduct the work of friction in the pipe,

$$Q'n'p-2\times 0.372\frac{Q'^3}{\pi^2 r'^5}$$

To make this work equivalent to that of a volume, Q of air, urged through a tube of the same dimensions, and with equal resistances for the two fluids, we establish the following equations:

1st. Equalizing the energy on entering the pipe:

$$Q'n'p=Q(n-1)p$$

or

$$Q'n'=Q(n-1);$$

2d. Equalizing the loss from friction in the pipe:

For water this work is

$$Q'h'\times 1000=\frac{2\times 0.00037}{\pi^2 r^5}lQ'^3\,1000.$$

For air it is

$$Qh\times 1.25n=\frac{2\times 0.00031}{\pi^2 r^5}lQ^3\,1.25.\,n$$

Equating these

$$Qh\times 1.25n=Q'h'\times 1000$$

or

$$\frac{2\times 0.00031}{\pi^2 r^5}lQ^3 1.25n=\frac{2\times 0.00037}{\pi^2 r^5}\times Q'^3\times 1000$$

or

$$31Q^3 1.25n=37Q'^3 1000.$$

we then have

$$Q^3=\frac{37}{31}\frac{1000}{1.25n}\times Q'^3=1.193\times\frac{800}{n}Q'^3$$

and

$$Q=Q'\sqrt[3]{\frac{954.4}{n}}.$$

For $n=2$ $Q=Q'\times 7.816$
" $n=3$ $Q=Q'\times 6.828$
" $n=4$ $Q=Q'\times 6.20$
" $n=5$ $Q=Q'\times 5.758$
" $n=6$ $Q=Q'\times 5.419$
" $n=7$ $Q=Q'\times 5.148$

The equation $Q'n'=Q\,(n-1)$ gives

$$n'=\frac{Q}{Q'}(n-1).$$

and consequently

			atm.
For $n=2$	$n'=1\times 7.816=3.91\,n$	or	7.82
" $n=3$	$n'=2\times 6.828=4.55\,n$	or	13.65
" $n=4$	$n'=3\times 6.20\ =4.65\,n$	or	18.60
" $n=5$	$n'=4\times 5.758=4.61\,n$	or	23.03
" $n=6$	$n'=5\times 5.419=4.51\,n$	or	27.09
" $n=7$	$n'=6\times 5.148=4.41\,n$	or	30.89

Thus with pipes of the same diameter, a volume Q of compressed air, and a volume Q' of water will yield the same effective work if

$$\frac{Q}{Q'}=\sqrt[3]{\frac{954.4}{n}}$$

if also the pressures n' of the water and n of the air bear the ratio

$$\frac{n'}{n-1}=\sqrt[3]{\frac{954.4}{n}}$$

It appears also that to realize this condition that the water pressure should not exceed 4.65 times the pressure of the air.

Another point of interest relating to water pressure or compressed air motors working in mines, is the influence of the difference of level between the two extremities of the conducting pipe.

If we suppose a vertical tube of a height H; n and N being the respective air pressures at the two extremities, we shall have the following relation :

$$\mathrm{Log}\,\frac{N}{n}=\frac{1.25\times H}{10333}$$

calling $1_k.25$ the weight of a cubic meter of air.

But the results of this formula differ so little from those obtained by considering the air incompressible, that we may, for all ordinary cases, calculate the increase of pressure, per unit of surface, at considerable depths by estimating the column of air by $1.25+n\times H$. This is expressed in atmospheres per square meter by dividing by 10333

or $$\frac{1.25\times n\times H}{10333}$$

This for $n=4$ and $H=100$ meters is

$$=0.0484$$

consequently $N=n+0.0484=4.0484$

the logarithmic formula above gives

$$N=4.049$$

a difference of only 0.0006 of an atmosphere for a difference of level of 100 meters.

For 1000 meters the formulas give respectively for values of N; 4.484 and 4.516; a difference of only 0.032 of an atmosphere.

We may then in applying the formula to mines treat the air as we do water, and consider the augmentation of pressure at the bottom as due to the weight of a column of fluid of the same density throughout.

So that for a column of vertical height H we have for pressure per square metre due to height,

for air $H\times 1.25\times n$

for water $H\times 1000$

This pressure is reduced, 1st, by the friction of the fluids; and, 2d, by the counteracting pressure of the atmosphere or rather of the increase of atmospheric column. This latter would be the same for both kinds of motor and would be equal very nearly to 1.25 H kilograms per square meter.

The resistance due to friction is for the air, represented by a column equal to

$$\frac{2c}{r}HV^2,$$

and by a pressure equal to

$$\frac{2c}{r}HV^2\times 1.25\,n$$

For the pressure lost would be equal to

$$\frac{2c'}{r}HV^2\times 1000,$$

the velocity V being the same in both cases.

Consequently the pressures, after making the deductions, would be

For air

$$H\times 1.25\,n\left(1-\frac{2c}{r}V^2\right)-H\times 1.25.$$

For water

$$H\times 1000\left(1-\frac{2c'}{r}V^2\right)-H\times 1.25.$$

If we make

$$n=4,\ V=1 \text{ and } r=0.10,$$

we shall have the effective pressure, for air,

$$5H(1-0.0062)-1.25\,H=H(5\times 0.9938-1.25)=H\times 3.719$$

and for water,

$$H\times 1000(1-0.0074)-1.25H=H(992.6-1.25)=H\times 991.35.$$

If $H=100$ we shall for pressure per square meter, due to difference of level; for the air 371.9 kil. which for $V=1$ and $r=0.10$ would represent a supplementary work of $371.9\times 0.0314=11.68$ kilogram-meters, or 0.156 horse-power.

With water the supplementary work for the same conditions would be :

$$99135\times 0.0314=3112.82^{\text{ km}}.$$

$=41.50$ horse-powers or 266 times as much as from the same volume of air at four atmospheres pressure.

For a pipe of $0^m.05$ radius and a velocity of one meter, the effective work of water at 100 meters becomes 10.3 horse-power; at 400 meters it becomes 41.2, and if for this depth the radius is made $0^m.10$ the effective work$=166$ horse-power.

It is true that in most cases the water used for such purpose in mines would require pumping out again; but this requires no unusual equipment. The drainage of mines by pumping engines is a constant factor of mine working. These engines are usually steam pumps yield-

ing an efficiency of 75 to 80 per cent. of the power of the engine.

Compressed air, on the other hand requires for the compression, a special apparatus, in which not more than a third of the work is rendered effective.

The greater pressures required for water motors would demand stronger and more costly tubes. But it may be added that in working the galleries of mines a descent of the water from the motor to the well of the drain pump would frequently afford a source of power.

A recapitulation of the foregoing is exhibited in the following formulas:

The effective work of air compressed without heating is

$$E=\frac{1-\frac{1}{n}}{2.3 \log n},$$

and

$$E=\frac{0.29\left(1-\frac{1}{n}\right)}{n^{0.29}-1},$$

when we consider the air heated to the full extent due to the compression.

Water meets in the pipes greater resistances than air; but for the same volume transmitted the loss of work from this cause is the same for the two fluids if the radii of the conduits have the ratio:

$$\frac{r'}{r}=\sqrt[5]{\frac{1193}{1{,}25n}};$$

the weight of the cubic meter of air being 1.25 kil.

Both air and water in conduits of the same diameter yield the same effective work at the ends if the volumes Q and Q′ and the pressures n and n' bear the following proportions:

$$Q=Q'\sqrt[3]{\frac{954.4}{n}}$$

$$n'=\frac{Q}{Q'}(n-1)=(n-1)\sqrt[3]{\frac{954.4}{n}}.$$

Finally, in a descending column the increase of useful pressure per square meter due to the weight of the fluid is, for a height H and velocity V,

for air

$$H\times 1.25n\left(1-\frac{0.00062}{r}V^2\right)-H.1.25$$

and for water

$$H\times 1000\left(1-\frac{0.00074}{r}V^2\right)-H.1.25.$$

We may conclude then that although compressed air possesses undoubted advantages as a motive power in mines, where machines run with a high velocity and a shock, as do the several drilling machines, for ordinary service the high pressure water engines are preferable on the score of efficiency and economy.

THE MOST ANCIENT LAND SURVEY IN THE WORLD.

From "The Building News."

HERODOTUS, the father of history, tells us that the science of geometry originated in Egypt, where the practice of land-surveying was first rendered necessary by the frequent obliteration of landmarks, through the periodical overflows of the river Nile. Plato ascribes the invention of geometry to Thoth. Iamblichus says that it was known in Egypt during the reign of the Gods; and Eustathius, in speaking of an age long before the Greeks were sufficiently advanced to study or practice the art, says that the Egyptians "recorded their march in *maps*, which were not only given to their own people, but to the Scythians also, to their great astonishment." The frequent changes of surface must have rendered the land-surveyors' a rather busy profession in ancient Egypt, and a considerable body of them were employed by Rameses III., whose office is thus described by Herodotus: "If the river carried away any portion of a man's lot, he appeared before the king and related what had happened, upon which the king sent persons to examine, and determine by measurement the exact extent of the loss;

and thenceforth only such a rent was demanded of him as was proportionate to the reduced size of his land. From this practice, I think, geometry first came to be known in Egypt, whence it passed into Greece." Whether these ancient land-surveyors' made plans of the land they measured we cannot say, because among the copious records of Egypt no agricultural plans, so far as we can at present remember, have yet been found. There are some plans remaining of royal tombs, with dimensions carefully figured in cubits, and also of the turquoise mines of Wadi-Magarah, fac-similes of which have been published by the German Egyptologist, Dr. Lepsius; and there are verbal records of the boundaries of particular lands, but none of the maps mentioned by Eustathius, or of those which possibly were drawn by the surveyors of Rameses or their successors.

Discoveries recently made, however, at the British Museum among the cuneiform inscriptions on the terra-cotta tablets of ancient Babylon render it questionable whether the Babylonians should not have at least equal credit with the Egyptians, for the discovery of the science of geometry, and of its application to land-surveying and the delineation of plans. The country between the Euphrates and the Tigris was very early inhabited by a land-owning population, and was subject to the same vicissitudes of periodical overflow by the rivers as Egypt; and like circumstances produced similar effects upon their progress in science and arts. Laws for the regulation of property in land may be traced as far back as the days of the Kassite kings, B.C. 1656, which are written in the very earliest Turanian, or Accadian, dialect of the country, and which have just been translated by Mr. St. Chad Boscawen. Several curious particulars are found in these most ancient tablets. For example, it appears most clearly that the women of Babylonia could hold real property, that land could be mortgaged, and that it could be pledged, together with other things which modern civilization does not allow. Thus one tablet says: "His house, his grove, his field, his slaves, male and female, for silver he has pledged." We learn also that the interest charged upon these transactions was often as much as 30, and sometimes even 70 per cent.

The actual definition of the boundaries of land was effected in Baylonia by boundary stones, on which were carved not merely a statement of the boundaries, but words which constituted the stone itself the actual deed of gift or sale. One of the most noticeable of these boundary stones in the British Museum is a large stone bearing an inscription of Merodach-baladan I., B.C. 1200, presented by the proprietors of the *Daily Telegraph.* It records a gift by the King of a plot of land to a person named *Merodachsum Izakir*, as a reward for political services. It gives no dimensions, but carefully describes all adjoining properties, and is attested by many witnesses. Another conical black stone, dated B.C. 1150, is extremely interesting, as giving the price paid for the purchase of the field—viz., 616 *mana* of silver; but inasmuch as this price was paid in kind, not in cash, we have an enumeration of the different articles, with their respective values, among which are: "One chariot, with its harness, for 100 silver; six riding horses, equal to 300 of silver; a cow in calf, some asses and mules, as well as numerous pieces of cloth." This stone also gives us the name of the ancient land-surveyor, who not only defined the boundaries, but also assessed the value of all these chariots, cows and calves, and asses and mules. Let the land-surveyors of the 19th century learn to reverence the name of this man, who, until Mr. Boscawen unearths some still older tablet, must remain the father of their art. His name was Sapiku, the son of *Merodach-baladhu*, and he is expressly called *Masakhu*, the field-measurer.

The number of documents (that is, terra-cotta tablets) which the Museum now possesses in relation to the commercial and land transactions of ancient Babylon and of Assyria is very great, a collection of more than 2,000 having been purchased at Baghdad in 1875. Mr. Boscawen published an account of some of these last year in a literary contemporary,* showing that they formed a tolerably complete record of the business transactions of a great Babylonian firm,

* The *Academy.*

who traded under the name of Egibi & Sons, as bankers and state land agents. Their records relate to every kind of transaction—land sales and leases, loans of money, mortgages, sales of slaves, and dealings in all kinds of property—and the documents show that they traded in this manner from the first year of Nebuchadnezzar, B.C. 605, till the last of Darius Hystaspes, B.C. 486, a period of about 120 years. There are many interesting facts as to the daily life of the ancient people to be gathered from them, but that which it is our present purpose only to notice is the tablet which contains, not simply a description, but an actual *plan* of the land referred to in the document, just as plans are now drawn on parchment in the margins of leases. This, we think we may safely say, is at present the oldest known land-survey in the world. It is drawn on a tablet in dark terra cotta, about 6 inches by 3¼ inches, and represents a plot of land about 8½ acres in area. The inscription at the top informs us that it is the plan of "A field in the high road on the banks of the river or canal," Nahr Banituv. The name of the river, however, is obliterated, and its place has been supplied by Mr. Boscawen from information drawn from other tablets relating to adjoining property. The estate is divided into three pairs of parallelograms, to which are added two more similar-shaped plots, and an irregular trapezoidal piece. The dimensions are all given in cubits, or fractions of cubits, most carefully figured on the drawing. Taking the Babylonian cubit as 20.475 English inches, the greatest length of the estate would be, from north to south, 1646 cubits, or 936 yards 0 feet 5 inches English. The width on the northern border on the edge of the highway is 84 cubits=140 feet. The dimensions on the southern part being much defaced, it is difficult to ascertain the length of the base line. On the east side the curve is most carefully measured, its circumference being 120 cubits, or 200 feet. A small dimension has been marked in the interior of the arc, which evidently represented its radius, but it is unfortunately obliterated. The northern boundary is the highway, or, as it is called in another document, "the royal highway." (It is interesting to notice such a very ancient use of our present common phrase, "the king's highway.") The western side adjoins the lands of Ipriya and Buruga, the son of Taria, the son of the Chief Builder, and this latter person is the owner also of the land on the southern boundary. The eastern side and the upper portion adjoin the lands of Nabu-sar-ibni, and another portion adjoins the lands of Kasiya, the son of Dibzir, the son of Pitu-sar-babi. It would seem strange for a modern surveyor to mark upon his plan, not only the name of his client's neighbors, but those of their fathers and grandfathers, yet this practice has revealed to us the fact that the ancient Babylonian "Chief Builder," or architect, was a person of some consequence, who left lands behind him, and grandchildren to be proud of their descent from him; and not the serf, or servant, which he was mistakenly represented to be in one famous modern picture.

As an example of the system of mensuration, and curious method of computation of the area, which was according to the amount of corn seed required to sow it, we make the following extract from a tablet dated in the third year of Nabonidus, king of Babylon :

1. 949 cubits on the upper side towards the west a boundary is fixed.
2. By [the land of] Nabu-sum-utsir, the giver of the field.
3. 949 cubits on the lower side towards the east the boundary is fixed by the land of Nabu-sar-ibni, son of Marducu.
4. 40 cubits the upper headland, a boundary line is fixed by the king's highway on the bank of the canal of Banituv.
5 40 cubits the lower headland, a boundary is fixed by the other portion of the field.
6. For this field, and this portion, five measures of corn seed. A field with the wells attached.
7. A valuation of 5 epha., 8 measures of corn seed.

This is the first measurement.

This represents the measurement and sowing area of the first portion of the land sold in the tablet. A second portion which joins on to the southern border, is also computed by a similar arrangement. A summary of the two results is given, and the price in silver, according to the market value of corn, is computed and entered as the price of the land. A guarantee of about one-tenth per cent. is required and given as security for the fulfilment of the clauses of the

deed. The names of seven witnesses who attest the deed, by affixing their *nail-marks*, and the scribes, who append their seals, testify to the legal character of the document.

Such was the legal procedure in the conveyance of land 2,500 years ago in ancient Babylonia. How little it differs from the legal acts and deeds which are daily transacted in our modern Babylon of London, and in this Great Britain which has just assumed new responsibilities in relation to the old country whence these antiquities have been exhumed!

APPARATUS FOR DETERMINING THE RESISTANCE OFFERED TO SHIPS BY EXPERIMENTS ON THEIR MODELS.

By A. LETTIERI.

From "Rivista marittima," Abstracts published by the Institution of Civil Engineers.

This is an apparatus for experimenting on the resistance offered to the models of ships. The inventor considers that the determination of the resistance encountered by a vessel moving at different velocities in still water is a most important question, which has been solved by Mr. Froude. The law which this gentleman has formulated, by which to deduce the resistances met by a vessel from those encountered by its model, Signor Lettieri considers to have been fully verified by the experiments made by Mr. Froude on the "Greyhound" and its model.

The further prosecution of similar experiments Signor Lettieri thinks useful, or even necessary, with the view of ascertaining, before the launch of a vessel, the curve of the resistance that it will encounter with different loads and displacements. Being unacquainted with the apparatus used by Mr. Froude, Signor Lettieri has invented one of his own, the description of which he illustrates with a drawing.

In experiments of this nature the elements to be determined are two: the uniform velocity, and the resistance encountered at that velocity. The first of these is obtained by the measurement of the space passed through in a unit of time. It is, therefore, desirable to have an apparatus which shall graphically denote this velocity by a curve, and refer it to a measure of the resistance.

To effect this, Signor Lettieri has designed a vertical cylinder (the drawing shows the length to be fourteen times the diameter, but neither scale nor dimensions are given), which revolves on a fixed axis. The upper part of this axis sustains a pulley, and a second pulley is fixed beneath the cylinder, with a small drum on its axis. A line attached to the drum passes over the upper pulley, and sustains a scale pan, to which is fixed a pencil, the point of which presses against the cylinder. The model is attached by a line to the lower pulley, so that the descent of the weight corresponds to the movement of the model through the water; while the weight itself is a measure of the resistance. Movement is given to the vertical cylinder by means of a pair of conically toothed wheels, one of which is attached to the cylinder itself. The motion of the latter being thus made uniform, and its velocity known, the curve traced on it by the pencil will indicate the relation between the movement of the model and that of the cylinder, and will form a regular spiral when both movements are uniform. The remainder of the Paper is occupied by an algebraical investigation of the curves thus to be obtained, and by the relation between the weight placed in the scale pan, and the resistance encountered by the model in its passage through the water.

Fifty sailors were placed in one of Mr. Berthon's twenty-eight feet collapsing boats at Portsmouth, for the purpose of testing it. The sea was very lumpy, but the boat, which is capable of carrying eighty men, behaved perfectly to the satisfaction of those under whose superintendence the trial was made.

MECHANICAL CONVERSION OF MOTION.

By GEORGE BRUCE HALSTED.

Contributed to Van Nostrand's Magazine.

CAUSE AND DESIGN OF THIS PAPER.

By mathematicians in the last four years has been created a branch of their science, which is so practical that it seems as if its results need only to be put before mechanicians in order to produce very important applications.

The fact that these results have been, and could have been, attained only by mathematicians, has tended, we fear, to frighten away practical men from a subject, of which a great part is capable of being so simply put as to furnish at once a new and beautiful weapon in the field of mechanical contrivance. This should be of especial interest in America, the land of practical applications; and so we have attempted to bring here into connection the new achievements with some of the old ones they seem suited to supersede, confidently leaving the rest to that sharp-sighted ingenuity for which our land is famous.

HISTORICAL INTRODUCTION.

No way is perhaps better fitted to pleasantly awaken interest than the prefixing of a slight historical sketch of a chapter of progress, which seems to furnish a very beautiful example of how the torch of science is passed from hand to hand, from land to land.

It does not need an expert to appreciate the theoretical interest and practical importance of being able to draw a straight line, or convert a straight thrust into circular motion, and *vice versa;* yet perhaps one not acquainted with the subject will feel somewhat incredulous, when told that this was never accurately accomplished before the year 1864, when a method of doing it exactly was discovered by M. Peaucellier, then an officer in the French army. This method we intend to present and explain; but meanwhile we will trace briefly its history and progress.

FIRST ISOLATED FACT.

He first announced it in general terms, in the form of a question in the "Nouvelles Annales de Mathematiques," 1864. He did not, however, seem fully to appreciate the importance of what he had done; nor did his discovery catch the attention of any one prepared to see its value, so it fell into oblivion for six years.

Yet there was at this very time a great mathematician, Dr. Tchebicheff, in Russia, working on this very question, and, in fact, trying to prove the *impossibility* of the exact conversion of circular into rectilinear motion.

Now, it would be interesting to investigate how it came about, that in 1870, only six years after its first discovery, this wonderful conversion was re-discovered just in the right place, that is, in Russia, by one of Tchebicheff's own students, named Lipkine.

His professor obtained for this fortunate youth a substantial reward from the Russian Government; and this has since stirred up that most conservative body, the Institute of France, to confer its great mechanical prize, the "Prix Montyon," on Peaucellier, who gave, in 1873, a detailed exposition of his discovery, in the same journal which had published his first intimation nine years before.

Meanwhile Lipkine had presented the theory and description of his apparatus to the Academy of St. Petersburg in 1871, and exhibited a model of it at the Vienna Exposition in 1873.

THROUGH RUSSIA TO ENGLAND.

Some months after, Dr. Tchebicheff happened to visit England, and there Prof. Sylvester asked him about the progress of his proof of the impossibility of the exact conversion of circular into rectilinear motion. Tchebicheff answered that, far from being impossible, it had actually been accomplished, first in France, and subsequently by a student in his own class. He then made a rough diagram of the instrument, which consists of seven links. Shortly after this interview, Dr. Garcia, the eminent musician, and inventor of the laryngoscope, happened to visit Prof. Sylvester,

and being shown the drawing, brought under his cloak next morning to the Professor a model, constructed with pieces of wood fastened together with nails as pivots, which, rough as it was, worked admirably, and drew forth the most lively expressions of admiration from some of the most distinguished members of the Philosophical Club of the Royal Society.

Soon after, Prof. Sylvester exhibited the same model in the hall of the Athenæum Club to his friend Sir Wm. Thomson, "who nursed it as if it had been his own child; and when a motion was made to relieve him of it, replied, 'No! I have not had nearly enough of it: it is the most beautiful thing I have ever seen in my life.'"

THE DEVELOPED THEORY.

Prof. Sylvester's appreciation carried itself over from admiration to accomplishment. He changed what seemed an isolated fact into a grand theory. He proved that every possible algebraical curve may be described by link-work. In a lecture before the Royal Institution he stated that we are able to bring about any mathematical relation that may be desired between the distances of two of the poles of a linkage from a third, and are thus potentially in possession of a universal calculating machine.

He exhibited and worked a cubic-root-extracting machine constructed on this principle, and claimed to have given the first really practical solution of the famous problem proposed by the ancients, of the duplication or multiplication of the cube.

Fired by this lecture, two young Englishmen, graduates of Cambridge, Mr. H. Hart and Mr. A. B. Kempe, took up the subject, and have been carrying it on with brilliant success.

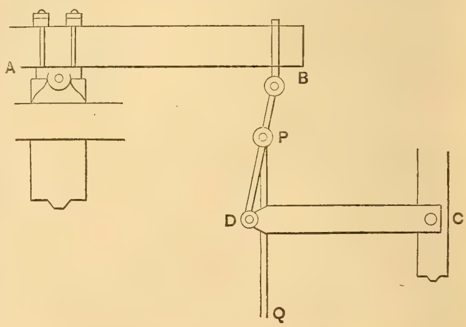
SOME RESULTS.

But now, perhaps, the reader begins to fear that our promise of simplicity was deceptive, and the subject must be too complex and difficult for a practical man.

This is very true in regard to its purely mathematical side;* but it is surprising how easily many of the results can be stated and explained to a person even entirely ignorant of mathematics, that dreaded science.

In addition to its theoretic interest, the direct importance of one of its applications is recognized when we consider, that in many machines and pieces of scientific apparatus, it is requisite that some point or points should move accurately in a straight line with as little friction as possible. If we are forced to use as guides planes ground smooth, the wear and tear produced by the friction of sliding surfaces, and the deformation produced by changes of temperature and varying strains, render it of real consequence to obtain, if possible, some more accurate and easy method which shall not involve these objectionable features.

As long ago as 1784, James Watt made an attempt, which was thus described by himself in the specification of a patent: "My second new improvement on the steam-engines consists in methods of directing the piston-rods, the pump-rods, and other parts of these engines, so as to move in perpendicular or other straight or right lines, without using the great chains and arches commonly fixed to the working beams of the engine for that purpose; and so as to enable the engine to act on the working beams or great levers, both by pushing and by drawing, or both, in the ascent or descent of their pistons. . . The principle on which I derive a perpendicular or right-lined motion from a circular or angular motion, consists in forming certain combinations of levers moving upon centers, wherein the deviations from straight lines of the moving end of some of these levers are compensated by similar deviations, but in opposite directions, of one end of other levers."



* For the literature of the subject, see the complete list given in my article "Historical Sketch of Exact Rectilinear Motion," *Van Nostrand's Mag.*, Jan., 1878.

AB is the working beam of the engine; PQ the piston-rod or pump-rod, attached at P to the rod BD, which connects AB and another bar, CD, movable about a center at C.

"When the working beam is put in motion, the point B describes an arc on the center A, and the point D describes an arc on the center C; and the convexities of these arcs, lying in opposite directions, compensate for each other's variation from a straight line; so that the point P, at the top of the piston-rod or pump-rod which lies between these convexities, ascends and descends in a perpendicular or straight line."

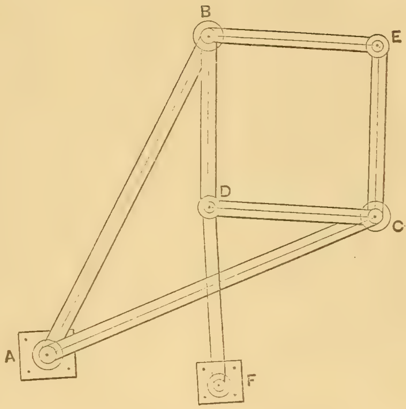
This would be most admirable if it were only true. In reality, the path of P lies on a figure 8, no part of which is straight; and it has been demonstrated that no combination of less than five links can enable us to get an accurate straight line, however short; while here, as we see, there are only three links, namely, AB, BD, DC.

The imperfection of Watt's movement led to other three-bar attempts and closer approximations; but with three bars it can never be solved. Still, if the swing of the beam of an engine be kept comparatively very small, the error will not be great; and so this Watt's Parallel Motion can be used, and we think still is used in the majority of English beam-engines, instead of the guides more usually employed in this country. That the guides can, however, thus continue successfully to compete with it, seems to us to depend upon the fact that it is necessarily inaccurate; and we see no reason why both should not be superseded by an application of one of the perfect rectilinear motions we desire to present.

FIRST ACCURATE SOLUTION.

The first accurate solution, as we have seen, was that of M. Peaucellier, in which seven links are used.

It consists of a rhombus composed of four equal links movably jointed at BCDE, and two other links movably pivoted at the fixed point A and at two opposite extremities BC of the rhombus. Take now an extra link FD, and pivot it to a fixed point whose distance from the first fixed point A is equal to the length of the extra link, whose other

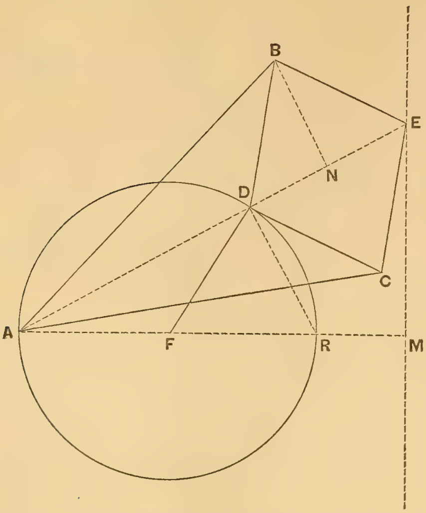


end is then pivoted to one of the free angles D of the rhombus. The opposite point E will now accurately describe a straight line, however the linkage be pushed or moved. The points B and C move in circles with radius AB, and the point D moves in a circle with radius FD, while E unvaryingly describes an absolutely accurate straight line perpendicular to a line joining A and F. So if we have our power in the form of the straight push of a piston, we have only to apply the end of the piston at E to have this straight push turned into circular motion at either of the other points we choose, and this too without the slightest tendency to side motion or wobbling, and consequently without any need of guides and their consequent friction and disadvantages. Again, if we have our power in the form of a circular motion and wish to transfer it to straight push or pull—for instance, to work a pump—we need only apply the circular motion at B, D, or C, to get perfect rectilinear motion at E.

PROOF OF ITS PERFECT ACCURACY.

All this may be rigidly proved by a little plane geometry as follows:

The angle ADR being always the angle in a semicircle, is always a right angle, and therefore the triangles ADR and AME having the angle at A common and the angles ADR AME equal, both being right angles, have consequently their third angles ARD AEM equal, and the triangles are similar. Therefore AD : AR :: AM : AE. Therefore AD . AE=AR . AM, moreover D may be on the circle.



But AR and AM once taken are constant, and their product AR.AM is a constant; so in order to devise a linkage such that when one of its points D is moved around in a circle, another of its points shall always remain on the identical chosen line EM, and shall consequently accurately describe that line, we must be able to discover such a linkage that however it may be moved, the product of the variable distances AD and AE shall always be exactly equal to the constant known product AR.AM, while in addition the movable point D always remains on the variable straight line AE. Now see how beautifully our linkage answers these difficult requirements and gives us the long-desired solution. On DE, the part of the line ADE which is exterior to the circle, construct, using DE as diagonal, any equilateral rhombus, as for instance BDCE, of four links jointed together so as to move easily. Pivot to B and C the two equal links AB, AC. Now from the symmetry of this linkage, however it be moved on its joints, the points A, D, E always are in a straight line, and the radius FD keeps the point D always on the given circle. Drop the perpendicular BN, and we always have DN=NE.

$$\text{Now } AB^2 = AN^2 + BN^2$$
$$BE^2 = EN^2 + BN^2;$$

therefore subtracting,

$$AB^2 - BE^2 = AN^2 - EN^2 = (AN + NE).(AN - NE) = AE.AD,$$

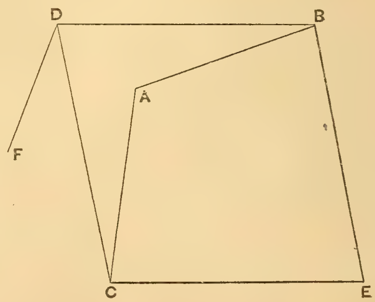
and since the bars AB and BE once made are of constant length, therefore the product AE.AD is constant, however much the distances AE and AD may vary individually as D is carried around the circle. Thus our desires are accomplished, and we have a machine for drawing straight lines, or turning circular into rectilinear motion, and *vice versa*.

A SUCCESSFUL APPLICATION.

Although this motion seems as yet almost entirely unknown to ordinary mechanicicans, yet it has been already applied in a beautiful manner to the air-engines which are employed to ventilate the Houses of Parliament in England.

The ease of working and absence of friction and noise are said to be very remarkable. Even the workmen there never tire of admiring their graceful and silent action. The engines were constructed and the Peaucellier apparatus adapted to them by Mr. Prim, the engineer to the Houses, of whom Prof. Sylvester tells the story that, conversing with him one day, just before the first engine was to be made, the Professor happened to mention that he supposed, of course, Mr. Prim knew that the point A need not be outside the rhombus but might be taken inside it, and the two equal bars thus made very compact. "Why! you don't mean to say so!" cried Mr. Prim. "Is it possible? Why then I can work it all from below, and won't have to knock a hole in the roof, as I thought I'd have to."

Prof. Sylvester gives this as an illustration of how an engineer of exceptionally good capacity will not see things which, to a mathematician appear perfectly obvious.



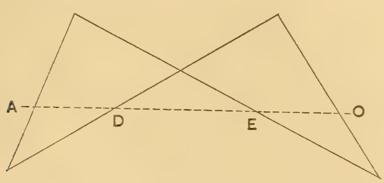
The form mentioned is given in the adjoining figure, where A and F are the fixed points and DF the extra link, the lettering of the two previous figures being retained. Omitting the extra link, this is called the negative Peaucellier cell, the one first given being called the positive cell.

ANOTHER APPLICATION.

Mr. Penrose, the eminent architect to St. Paul's Cathedral, has put up a house-pump worked by a negative Peaucellier cell, to the great wonderment of the plumber employed, who could hardly believe his senses when he saw the sling attached to the piston-rod moving in a true vertical line, instead of wobbling, as usual, from side to side. A sister pump of the ordinary construction stands beside it, but the former, although quite as compact as its neighbor, throws up a considerably larger head of water with the same sweep of the handle. Its elegance and the frictionless ease with which it can be worked (beauty, as usual, the stamp and seal of perfection) have made it the pet of the household.

RECIPROCATING PROPERTY OF CELL.

Now to return to our cell, we see that its peculiar power depends on the fact that, however it be deformed, the product of the varying lengths AD, AE, always remains constant. If when these points coincide, the distances AE and AD be taken equal to one foot and then the cell be moved again, when AD takes respectively the lengths 1, $\frac{2}{3}$, $\frac{1}{2}$, $\frac{1}{3}$, &c., then AE will be found to assume the lengths 1, $1\frac{1}{2}$, 2, 3, &c., showing that the length of one is so governed by the length of the other that their product must remain constant.

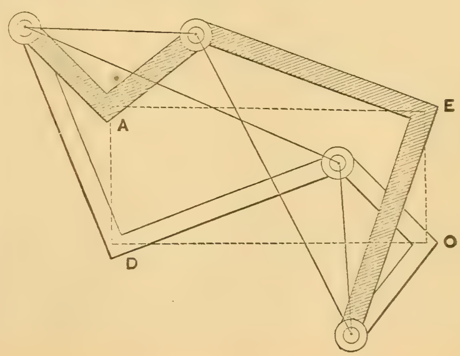


Now Mr. Hart found that if he took four bars and made a linkage in which the adjacent sides are unequal and two cross as in the figure, and then took four points on the four links dividing the distances between the pivots in the same proportion, those points will always remain in a straight line and possess the peculiar property just adverted to, so that the product AD . AE is constant. So also is OE.OD, and also AD.DO and AE.EO. So we see immediately that we may employ Hart's cell of only four bars exactly as we employed Peaucellier's of six bars, and by fixing one of the points as A, and pivoting our extra link to another as D, we can get straight line motion with only five bars, which is the least number possible, as has been absolutely demonstrated.

THE QUADRUPLANE.

A beautiful and important extension of this discovery was made at the same time by Prof. Sylvester and Mr. Kempe. Prof. Sylvester has given quite an elaborate description of it, but I use Mr. Kempe's own words as being simpler. "If we take the contra-parallelogram of Mr. Hart and bend the links at the four points which lie on the same straight line, through the same angle, the four points, instead of lying in the same straight line, will lie at the four angular points of a parallelogram of constant angles—two the angle that the bars are bent through and the other two its supplement—and of constant area, so that the product of two adjacent sides is constant."

If we keep the lettering of the last figure, take the holes or points in the middle of the links and bend them through a right angle as the simplest, we have the figure here given. The four holes now lie at the four corners of a right-angled parallelogram, and the product of any two adjacent sides, as AD.AE, is constant.



It follows that if A be fixed and D pivoted to the extremity of the extra link, whose other extremity is always pivoted to a point equidistant from A and D, the point E will describe a straight line differing in direction from the line it described before the bending by precisely the same angle the bars have been bent through, in this chosen case by a right angle.

By looking at the figure it is seen that the apparatus, which for simplicity has been described as formed of four straight links which are afterwards bent, is really formed of four plane pieces on which appropriate points are chosen. This is why it is called the "Quadruplane" by Prof. Sylvester, who says: "The quadruplane gives the most general and available solution of the problem of exact parallel motion that has been discovered, or that can exist. I say the most available, for it is evident, in general, that piece-work must possess the advantage of greater firmness and steadiness, from the more equal distribution of its strains, over ordinary link-work."

THE PLAGIOGRAPH.

From the ordinary pantagraph familiar to mechanicians, on application of this same idea, namely, turning two of its links into pieces or planes, gives a beautiful extension of it, called by Prof. Sylvester, its inventor, the Plagiograph. "Like the pantagraph, it will enlarge or reduce figures; but it will do more, it will turn them through any required angle." Thus the Plagiograph enables us to apply the principle of angular repetition (as, for instance, in making an ellipse with dimensions either fixed or varying it will, successively turn its axis to all points of the compass), to produce designs of complicated and captivating symmetry from any simple pattern or natural form, such as a flower or sprig. This should be found to place a new and powerful implement in the hand of the pattern-designer and architectural decorator.

ANOTHER IMPORTANT USE.

Finally, we have seen that in using a linkage to draw a straight line, the distance between the fixed pivots must always be the same as the length of the extra link. Now if this distance is not the same, the pencil-point describes, not straight lines, but circles. If the difference be slight, the circles described will be of enormous magnitude, decreasing in size as the difference increases. This property is of very high importance in in the mechanical arts for describing circles of large radius. Prof. Sylvester cites as example some circular steps outside St. Paul's Cathedral, which requiring repair, Mr. Penrose employed a Peaucellier cell to cut out templets in zinc for the purpose. The radius of the steps is about 40 feet; but to the great comfort and delectation of his clerk of the works, they were able to operate with a radius of not more than 6 or 7 feet in length.

These are but the simplest of the innumerable applications contained in, and immediately suggested by, the new science of linkage. Only let the practical mechanician begin to make for himself models of those here described, and we guarantee him a rich harvest of unlooked for results.

In the words of its founder, "I feel a strong persuasion that when the inertia of our operative classes shall have been overcome, this application will prove to be but the signal, the first stroke of the tocsin, of an entire revolution to be wrought in every branch of construction."

It is well for those who manufacture articles liable to decomposition to know that glycerine has the power of arresting fermentation to a remarkable degree. It is stated in the *Chemical Journal* that glycerine retards both lactic and alcoholic fermentations. One-fifth of glycerine added to milk at a temperature of 15 deg. to 20 deg. C. prevents it from turning sour for eight or ten days. One-half or one-third of glycerine, at the same temperature, retarded the fermentation of milk for six or seven weeks. At higher temperatures larger quantities are needed to produce the same results. The formation of hydrocyanic acid from amygdaline and emulsine is also retarded by glycerine. It becomes thus very serviceable in preventing the spoiling of various lotions. For this reason it is not unusual to add a small quantity to the preparation known as milk of roses, and also to almond paste. With regard to cosmetics, generally, the use of glycerine in small quantities may be recommended.

ON AERONAUTICS.

By RICHARD GERNER, M. E.

Written for Van Nostrand's Engineering Magazine.

Long before the locomotive and the steamship were thought of, man cast his eyes longingly over the vast expanse of atmosphere above him, and thirsted after the simple ability which a bird acquires so quickly, and which mankind, after centuries of study and experiments, has not even approximated to. Ovid has told us the tale of the feat of Daedalus in so natural a manner that we should love to think of it as a reality and it drives us on to further thought and experiment. Archytas is said to have constructed a flying dove, but we are sorry to opine that this must be classed among the legends and traditions rather than the facts which have come down to us from those days. There is but one possible means of rising into and traversing through the air faster than a bird, as a crusty but not humorless German professor informed us in 1812, and that is by means of our thoughts, and this too, after having led us through a work of 600 pages descriptive of aeronautical experiments and apparatus, which is all very fine but hardly satisfactory.

Since then, as many years have passed away as there are elements, and we are to this day as unable to go to China by any other means than land or sea as we were then. But is it really true that this sixty-five years long study and research has been to no purpose? Have we not even a clew towards the desired purpose to be effected?

Let us see what has been done in all this time; how the difficulties of the problem of aeronautics have been met and treated, and how far man failed and how far he has been successful.

Primarily, it was desired to produce a means of rising into the atmosphere. And so far as this is concerned, the human mind and ingenuity has experienced a triumph which will be as lasting as it has been successful.

But, paradoxical as it may seem, this success has been the means of delaying the progress of the actual science of aeronautics to a remarkable degree, as the popular mind has become engrafted with the idea that the art and science of ballooning would ultimately and inevitably lead to the solution of the problem. That this is not the case, we shall learn from an examination of the history, construction, principles and results arrived at by the balloon.

The Montgolfier Brothers are generally and popularly accredited with the invention of the balloon, and in so far as they were the first to construct such a thing they are not undeserving of the credit. But Prof. Charles, the Parisian physicist, invented and constructed a hydrogen balloon quite independently of them, and this has not been superseded to this day, while the hot air balloons of the Montgolfiers went out of practice a comparatively short time after their introduction.

The way the Montgolfiers got at their balloon, was as follows: At Annonay, in Vivarrais, not far distant from the very base of the Alps, they owned a paper mill, and here they had the daily opportunity of watching the formation of the clouds on the mountain slopes and then rising into the air. Both were scientifically educated; they often conversed over the causes of the flight of the clouds, and presently the thought occurred to them to imitate this natural phenomenon. But their experiments were a series of sad failures until Priestley's work on different classes of air and gases fell into their hands, wherein they found the possibility of the existence of gases, much lighter than air, discussed. It was only a question of enclosing such gases in a light envelope, but all trials to effect this with paper, failed.

After many vain experiments, they at last, in 1782, arrived at the desired result, but curiously enough, on premises which were utterly ridiculous. Their idea was that one of the principal causes why clouds arise in the air and there remain at rest, or are wafted about without falling to the earth, is electricity. Accordingly, they sought the production of a gas gifted with electric properties, and this production they thought to

effect by mixing gas of alkaline properties with non-alkaline. To this end, they burned straw and an organic substance, like wool, which was to produce the alkaline gases, under a square paper balloon of about forty cubic feet capacity, and to their delight, the balloon arose to the ceiling of the room. That it was simply the heating of the air in the balloon which effected its rising they hadn't the slightest idea. Instead, they thought to have discovered a new gas with remarkable properties and gained many followers, until Saussure, in the following year, terminated the bitter controversy which had arisen, by performing the simple experiment of inflating a small paper balloon by carefully inserting a red hot iron into it, and causing it to rise.

The great desideratum had been arrived at, and now it only remained to carry the thing into practical execution, and accordingly, the Montgolfiers built, in the same year, an apparatus of a diameter of 38 feet, which weighed 450 lbs., and carried an additional weight of 400 lbs., and on the 4th of June, 1783, this airship ascended from a public square in Annonay, to the amazement of the entire inhabitants of Vivarrais. The balloon was constructed of linen pieces simply put together by means of buttons and buttonholes, lined with paper and covered with a string net-work. And on a wire gauze under the opening, ten pounds of straw and wool were burned. Unfortunately, the spectacle only lasted ten minutes, the balloon having risen 1960 feet, and horizontally carried along 7200 feet.

The corporation and inhabitants of Paris received the news of this exhibition, and, as is usual with that capital, went wild over it. The Academy of Science extended an invitation to the Montgolfiers to come and repeat the show. But the excitement was too great to await their coming, and within a few days, 10,000 francs had been subscribed, and Prof. Charles, the favorite physical scientist of the day, an energetic young man, was commissioned to spend this money in preparing a balloon sensation for the excited Parisians.

But Prof. Charles didn't treat the matter in the light of a public amusement. In speculations over the Montgolfiers' mysterious electric gas he didn't lose any time, but applied himself with energy to the feasibility of the employment of hydrogen for the filling of the balloon. Hydrogen was but little known then, and the idea of operating with something like 1000 cubic feet of this dangerous gas, was an appalling one. However, Charles went to work fearlessly and with a will, and the Robert Brothers, who were clever mechanicians, filled his order for a balloon constructed of fine silk in a short space of time, finishing the same Aug. 23, 1783. This huge bubble was filled, on plans entirely original, by air of a barrel serving for the taking up of the iron and water used for the generation of the hydrogen, two tubes leading through holes cut into the head, one into the interior of the balloon, and the other for the introduction of the sulphuric acid. This rude apparatus brought up many difficulties, which threatened the failure of the undertaking. The heat generated by the action of the acid upon the iron, converted a large amount of water into steam, which entered the balloon with the gas and there condensed. Then, also, sulphureted hydrogen, finding an entrance into the balloon, and dissolving in the water formed on the interior of the envelope, might prove fatal in attacking the light fabric. It was necessary, furthermore, to direct streams of water on the balloon to cool it off. It took four days to fill a space of 943 cubic feet about two-thirds full, and 1000 pounds of iron and 500 of sulphuric acid, to produce the 35.75 of hydrogen necessary. But of this 31.75 were lost.

On the 27th of August, at 5 P.M., this balloon arose over the heads of 300,000 spectators assembled in the pouring rain on the Champ de Mars. It maintained a respectable height for about three quarters of an hour and then fell to the ground at Econe, containing a huge rent, owing to Robert having inflated it too much; and in the upper regions, where the air is lighter, the gas in the balloon of course expanded and burst its flimsy shell. This balloon was greeted by the peasants as a huge monster and hunted to death with pitchforks and fire-arms amidst the wildest excitement.

Whence we see that Prof. Charles is

quite as much entitled to the honor of the invention of the balloon as the Montgolfier Brothers are.

On the 1st of December, 1783, he and Robert made an ascent, and he was the second human being that had ever risen above the level of the highest peaks on earth. The first was Pilatre de Rozier, on the 21st of November, but as Charles had published his intent already on the 28th of September, before Rozier had thought of so doing, we must also give him some credit herein. Rozier's ascent was made in a clumsy balloon, 63 feet high, of a diameter of 51 feet, and was of Montgolfier's manufacture. He met with his death, the penalty of his aeronautical intrepidity in 1785; the first victim of the balloon. Charles' balloon had had a capacity of 9200 cubic feet, and had been 26 feet in diameter. Assuming its filling at 6000 cubic feet, the gas weighs 64.5 lbs., taking the moisture into consideration, while 6000 cubic feet of air weigh 516 lbs. The difference is, therefore, 451.5 lbs. As much less than this figure which the balloon, with all its accompanying paraphanalia, weighs, so much will it be capable of carrying into the bargain. Had the same balloon been filled with illuminating gas, this difference would have been 387 lbs.

Europe now began to indulge in the wildest speculations, which ended, unhappily, for the time being, in smoke. The excitement passed over like so many others had done before them and will do after them; many had lost their fortunes and peace of mind in the pursuit of the subject, and a clever few had become millionaires.

Since then, the art, if not the science, of ballooning has become greatly extended, and over 10,000 ascents have been made, of which the celebrated English balloonist, Greene, towards the end of the year 1849, completed 365. Of 1500 aeronants, but 12 have met with an untimely death.

The ascent which Gay-Lussac made in 1804 was the most remarkable for the facts with which it has enriched science, and for the immense height of 23,000 feet above the level of the sea which he attained. At this height, the barometer descended to 12.6 inches, and the thermometer, which was 1° C. on the ground, was 9° below zero. In these regions, the dryness was such on the day of Gay-Lussac's ascent, that hygrometric substances, such as paper, parchment, &c., became dried and crumpled as if they had been placed near the fire. The respiration and circulation of the blood were accelerated in consequence of the great rarefaction of the air. Gay-Lussac's pulse made 120 pulsations in a minute, instead of the normal number of 63. At this great height, the sky had a very dark blue tint, and an absolute silence prevailed. Rozier before him had also made ascents for scientific purposes, but with no recordworthy results.

One of the most remarkable of ascents was made by Mr. Glaisher and Mr. Corewell, Sept. 5, 1861, in a large balloon belonging to the latter. This was filled with 90,000 cubic feet of coal gas, the weight of the load being 600 lbs. After 1 hour and 28 minutes, they had reached a height of 15,750 feet, and in eleven minutes after, a height of 21,000 feet, the temperature being 10.4° C. below zero; another eleven minutes, and they were 26,200 feet high, with the thermometer at 15.2° C. below zero; still another two minutes, and the height attained was 29,000 feet, and the temperature 16° C. below zero. At this height, the rarefaction of the air was so great, and the cold so intense that Mr. Glaisher fainted, and could no longer observe. According to an approximate estimation, the lowest barometric height they attained was 7 inches, which would correspond to an elevation of 36,000 to 37,000 feet.

We have seen that the use of hot air has given way to that of hydrogen, and the latter, in many cases, to that of coal gas, which is preferred on account of its being cheaper and more easily obtained. A balloon of the ordinary dimensions, which can carry three persons, is about 16 yards high, 12 yards in diameter, and its volume about 680 cubic yards; with its accessories, it weighs about 300 lbs., and alone, about two-thirds of that amount. The gas is passed into the balloon from the reservoir by means of a flexible tube. The balloon must not be filled quite full, as the atmospheric pressure diminishes as it rises, and the gas inside expanding in consequence of its elastic force, tends to burst it, as it

did in the case of Charles' first balloon. It is sufficient for the ascent if the weight of the displaced air exceeds that of the balloon by 8 or 10 lbs.

The rising and falling of the balloon is easy enough, and if it had not been long proved by direct experiment, Jules-Verne has done it for us to our complete theoretical satisfaction in his interesting work entitled "Five Weeks in a Balloon."

The aeronaut can tell whether he is ascending or descending, either by the barometer or by a long streamer attached to the car. The ascent is effected by throwing out the ballast of sand bags as the occasion requires, and the descent, by the opening of the safety valve on the top of the balloon which allows part of the gas to escape. In so doing, the aeronaut must bear in mind that he is sustaining an irreparable loss, and be careful how he expends the precious means.

As far as the horizontal motion of the balloon is concerned, that is beyond the power or desirability of the aeronaut; he becomes the plaything of the winds, attaining a velocity of from 66.66 to 116.66 feet per second. Garnerin and Capt. Sowdon, in 1802, on their trip from London to Colchester, in one hour completed 17.5 geographical miles, and Robertson, at Hamburg, about ten. The colossal balloon, which, decorated with 3000 colored lamps and a richly gilded crown, was liberated from the Place Notre Dame de Paris, in Paris, at 11 P.M., Dec. 4, 1804, in honor of the crowning of Napoleon, hovered over Rome at daybreak. Who will bridle such a velocity?

The only practical application which the balloon has experienced is in military reconnoitering, and this has been effected with great success at the battle of Fleurus, in 1794, at Solferino and more lately in the Franco-Prussian war.

And that is what has been done in 65 years, as far as the art and science of ballooning proper is concerned.

In addition, however, much more has been done, and as nearly much more to no purpose. The wildest and most improbable propositions have been advanced, and many have attempted to put these into practical operation. The difficulties, both practical and theoretical, are innumerable and overwhelming, whole libraries have been written on the subject, not a year passes by without adding to the literature already at hand, fortunes have been spent in the construction of designs and the carrying out of vague experiments, and that same Champ de Mars which witnessed the ascent of the first hydrogen balloon, has since witnessed countless failures, and on every one of these occasions, the unhappy apparatus has been ruthlessly destroyed by the mob to satiate its disappointment. There was Jacob Degen, a Viennese horologist, who, in 1812, received a good licking at the hands of a crowd for the failure of his plan; and then there was Lennox, who, in 1834, exhibited his notorious air-ship, the "Eagle," 160 feet high by 48 broad, by 63 feet long, capable of carrying 17 persons, in Paris, which was broken into a thousand pieces by the infuriated spectators. And still we are bid not to despair.

The trouble has been that the projectors of these flying machines have entirely ignored the voice of science; as soon as an idea would strike them, without stopping to enquire into its theoretical correctness, they would immediately plunge into the execution of their improvable schemes without a moment's deliberation, and the necessary result was failure.

The balloon has long been abandoned by scientific men as the foundation to the solution of the knotty problem. The most advanced thinkers have turned their thoughts in an opposite direction, and have come to regard flying creatures, which are all much heavier than atmospheric air, as the true models for flying machines. An old doctrine is more readily assailed than uprooted, and, accordingly, we find the followers of the new faith met by the assertion that insects and birds have large air cavities in their interior, that these cavities contain heated air, and that this heated air, in some mysterious manner, contributes to, if it does not actually produce, flight. No argument could be more fallacious. Many admirable fliers, such as the bats, have no air-cells, while many birds, like the apteryx, and several animals never intended to fly, like the orang-outang, and a large number of fishes are provided with them. It may, therefore, be reasonably concluded that flight is in no

way or manner connected with air-cells, and the best proof that can be adduced is to be found in the fact that it can be performed to perfection in their absence.

According to Dr. I. Bell-Pettigrew, the author of the celebrated work on "Animal Locomotion," and the scientist who was among the first of his time to point out the road to the true solution of the question of aeronautics, there are five primary causes on which all attempts have hitherto wrecked :

First.—The extreme difficulty of the problem. This very cause has given an attractive and fascinating air to the problem, and has hitherto prevented its calm deliberation.

Secondly.—The incapacity or theoretical tendencies of those who have devoted themselves to its elucidation. This cause is now happily eliminated, and like the first, will cease to come into consideration under the earnest application of their thought and time of men like Dr. Pettigrew to the subject.

Thirdly.—The great rapidity with which wings, especially insect wings, are made to vibrate, and the difficulty experienced in analyzing their movements.

Fourthly.—The great weight of all flying things, when compared with a corresponding volume of air. This difficulty will fade more and more as the aforementioned one is eliminated by patient study.

Fifthly.—As we have already stated in a former part of this paper, the discovery of the balloon, which has retarded the science of aeronautics, by misleading men's minds and causing them to look for a solution of the problem in the employment of a machine lighter than the air, and which has no analogue in nature. But it should be remembered, before condemning this circumstance as a difficulty, that the tendency of the new faith may be as erroneous in the end as that of the balloon, and that we have not lost so much after all, by wasting our time on the balloon in seeking for our solution, as we have thereby eliminated a factor from our equation, so to speak, which might have given us no little difficulty in the prosecution of so interesting, important and so complex a subject.

It should also be remembered that past experience has taught us that the genius of the inventor has been quite as important an element in the engineering institutions of the past as the research of the scientist, but, of course, the former is dependent in a great degree upon the latter, and as the scope of that research progresses and enlarges, so do the inventor's genius open new avenues of probable success. It is surprising how much the happy thoughts of the illiterate have contributed towards the progress of engineering and industry.

So we find that if we can trust the new faith, *i. e.*, the solution of the problem by animal flight, that the third difficulty aforementioned is the only practically remaining one. That we may trust in the new faith, such men as Dr. Pettigrew heartily and enthusiastically assure us.

The past trouble with the new faith was that it has been cultivated, on the one hand, by profound thinkers, who have never subjected their theories to experiments, and, on the other hand, by uneducated charlatans who have never subjected their experiments to scientific theory.

There remain many eminent men who still advocate the employment of a machine specifically lighter than air, whom we may style the balloonists; but the ideas which they advance have mostly been practically executed and found to be absurd. They reason that the first consideration is to raise the flying-machine, as it is to make a ship or locomotive go, and that the second consideration is to control this motion. And that is where they are fundamentally wrong, as the question cannot be treated similarly to locomotion on land and sea; and besides, a hundred examples have taught us the fallacy of their reasoning.

We must abandon the balloon altogether, as we have endeavored to show.

But the balloonists do not formulate the only irrational school; a second modern one is that section of the one believing that weight is necessary to flight, which advocates the employment of rigid inclined planes driven forward in a straight line, or revolving planes, *i. e.*, aerial screws.

The other section is more rational, and most likely the right one, trusting for elevation and propulsion to the flapping of wings. This section may be further subdivided into advocates of the vertical

flapping of wings, such as Borelli, Marey and others, and advocates of the partially horizontal flapping of wings, such as Bell-Pettigrew. The favorite idea of the disciples of the inclined plane scheme is the wedging forward of a rigid inclined plane upon the air. It may be made to advance either in a horizontal line, or made to rotate in the form of a screw, whence we also have this section subdivided, and both divisions have their adherents. The one recommends a large supporting area extending on either side of the weight to be elevated, the surface of the supporting area making a very slight angle with the horizon, and the whole being wedged forward by the action of vertical screw propellers. This was the plan suggested by Henson and Stringfellow. The former designed his his ærostat or flying machine, in 1843, and the latter, on Wengham's plan, exhibited his design at the Aeronautical Society's Exhibition, held at the Crystal Palace, London, in the summer of 1868. These formidable and scientific-looking things were never coerced into giving an exhibition of their pretended capacities, and it were therefore useless to consider them.

The first to apply the aerial screw to the air was Sir George Cayley, who, in 1796, constructed a small machine consisting of two corks fastened on either end of a vertical spindle, to the lower part of which is suitably secured the middle of a whalebone bow. To either end of the latter are attached strings which wind about the spindle, and thereby stretch the bow. In the corks are inserted a number of wing feathers from any bird, so as to be slightly inclined, like the sails of a windmill, but in opposite directions in each set. This instrument, after being wound up, readily rises in the air. Sir Cayley calculated that if the area of the screw was increased to 200 square feet, and moved by a man, it would elevate him. But it appears that he never tried it.

This model was immediately seized upon as the basis for a flying machine by a great many people. In 1842, Mr. Phillips succeeded in elevating, by means of revolving fans ; a model made entirely of metal, and which, when complete and charged, weighed two pounds. The fans were inclined to the horizon at an angle of 20°, and through the arms the steam rushed, on the principle discovered by Hero, causing the fans to revolve with great energy, so much so that the model rose to a great altitude, and flew across two fields before it alighted. The motive power employed in this instance was obtained from the combustion of charcoal, nitre, and gypsum. This is the first machine that steam ever raised into the air.

The French also seized upon the screw scheme with avidity, and Nadar, Pontin, d'Amecourt and de la Landelle, between the years 1853 and 1863, succeeded in constructing clockwork models, which not only raised themselves into the air, but also carried a certain amount of freight.

It will be readily understood that there is nothing gained by all these machines, and that they are even less efficient than the balloon, and much more costly. What if you can rise into the air with them, and ever so high at that? That is not the question; the question of rising in the air has been solved by the balloon; what we want is direction, and not elevation; the aerial screw is no more governable in this regard than is the balloon.

Whence it appears that we must reject the doctrines of the inclined plane school quite as much as those of the balloonists; and another important and troublesome factor has been eliminated from our equation. Let us see how soon we can get it down to "x equals to."

There now remains to be regarded the doctrines of those who believe in the flappings of wings, to secure the desideratum.

In 1860, Borelli published at Rome a two-volume work, "De Motu Animalium," and up to 1865, all the knowledge that we possessed on the subject is due to this distinguished physiologist and mathematician. He constructed an artificial bird in which the wing, consisting of a rigid spine, with natural feathers attached thereto, flapped vertically downwards, and this idea has been enthusiastically seconded by both Straus-Durckheim and Girard, and quite lately by Professor Marey.

Borelli opines that flight results from the application of an inclined plane, which beats the air, and he evolves,

amongst others, the following propositions from his arguments:

First—If the air strikes the under surface of the wing perpendicularly in a direction from below upwards, the flexible portion of the wing will yield in an upward direction, and form a wedge with its neighbor.

Secondly—Similarly and conversely, if the wing strikes the air perpendicularly from above, the posterior and flexible portion of the wing will yield and be forced in an upward direction.

Thirdly—That this upward yielding of the posterior or flexible margin of the wing results in and necessitates a horizontal transference of the body of the bird.

Fourthly—That to sustain a bird in the air the wings must strike vertically downwards, as this is the direction in which a heavy body, if left to itself, would fall.

Fifthly.—That to propel the bird in a horizontal direction, the wings must descend in a perpendicular direction, and the posterior or flexible portions of the wing yield in an upward direction, and in such a manner as virtually to communicate an oblique action to them.

Sixthly.—That the feathers of the wing are bent in an upward direction when the wing descends, the upward bending of the elastic feathers contributing to the horizontal travel of the body of the bird.

These arguments appear so plausible as to be acceptable to the superficial reader, and even to the philosophers of the past two centuries they have seemed correct in general. Many have changed his plans in detail and proclaimed their new discoveries to the world without giving Borelli credit for the same, and up to this date they have stood firm. The best proof of their invalidity lies in the unfortunate circumstance that they have never succeeded when applied to practice.

Prof. Owen, Macgillivray, Bishop, Liais and others, have added the word *backwards* to Borelli's *downwards.*

Bell-Pettigrew was the first to differ from Borelli and his votaries. He proves that the action of the wing is not downwards and backwards, but downwards and forwards, and that the other arguments stated are fallacious throughout. The artificial wings which he made of late differ from those recommended by Borelli and others in the mode of construction, in the manner in which they are applied to the air, in the nature of the power employed, and in the opinion of the necessity for adapting certain elastic substances to the root of the wing if in one piece, and to the root and the body of the wing if in several pieces.

He maintains that no part of the wing should be rigid; that, if the wing be in one piece, it should be made to vibrate obliquely and more or less horizontally, so as to twist and untwist and make figure-of-8 curves during its action, thus enabling it to seize and let go the air with wonderful rapidity, and in such a manner as to avoid dead points; that the entire wing must be under thorough control during a cycle of motion, and that steam, varying in intensity at every stage of the down and up-strokes, produced by a direct piston action, is the proper motive power; and that the root of artificial wings must be supplied with elastic structures in imitation of the muscles and elastic ligaments of flying animals.

The propounder of what has here been so very briefly referred to has not only the highest faith in his being the true method, by pointing to an early consummation of his plans, but ably and scientifically enters into the merits and minutiæ of his every assertion. His views are sustained by many eminent authorities, who predict its practical success; and we truly believe that the inventor's only chance in this direction is to study Bell-Pettigrew's propositions, ponder them over critically and make them the basis of his speculations and work.

But it must not be imagined that ballooning and aerial animal locomotion are the only foundations upon which both profound philosophers and hair-brained visionaries have built their plans and experiments.

Attempts have been made to harness trained eagles to balloons and other apparatus, and for a long time this possible solution of the question was agitated with fervor and enthusiasm. That this is not the ultimately correct solution is proved by the readiness with which it

was suffered to drop out of notice. A blunt, but well-meaning, individual in a technological journal lately remarked that if humanity couldn't produce any better than animal power to settle its engineering difficulties, it had better resume the furs and bone spears of its barbarous ancestry and give up civilization as a bad job. And we cannot help feeling as he does.

Of course, electricity has been suggested. We noticed a communication from an Australian in the New York *Herald* lately, who had a plan of aerial navigation on electric principles, and only wanted some cash to show the world that his principles could be carried into successful execution. Electricity, somehow or other, can do anything ; it is one of these grand, mysterious institutions that will be the future foundation of not only engineering, but of everything. Verne runs and lights his "Nautilus" with it, and this Australian is going to aero-Nautilus it on the same plan. People expect great things from electricity, especially since we can hear the grass grow in Philadelphia with it from New York, and perform other startling feats. People look knowing and hint at future immensities of achievement ; the unknown is always what people know most about ; ask an average man to extract a square root, to solve an equation of the second degree, or to perform some similar elementary operation, and he'll scratch his head and tell you that he isn't up in that sort of thing; but ask that same man about the future electricity and it is wonderful how much he knows about it, while the sages of all ages and parts of the globe are devoting their life-times to the study of its nature, and finally declare that they don't know anything about it. Ask a professor of mathematics what force is. He don't know. Ask a precocious student. Oh, he knows, and he'll tell you all about it; dealing in arguments and with propositions which are too profound for anybody to understand.

We cannot be too emphatic in warning the precocious inventor against attempting to overreach science. Experience has taught us that it leads to nothing. We do not mean to say that speculation should be abandoned, but we do not believe in building on a foundation which cannot be supported.

Bell-Pettegrew has given us a foundation which will stand. Build on that. Experiment on electricity if you will, don't build on deductions before a critical, scientific community has given them the stamp of validity.

TRANSMISSION OF POWER BY COMPRESSED AIR.

By ROBERT ZAHNER, M. E.

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I.

HISTORICAL NOTICE.

The application of compressed air to industrial purposes dates from the close of the last century. Long before this, indeed, we find isolated attempts made to apply it in a variety of ways; but its final success must be ascribed to the present age—the age of mechanic arts—an age inaugurated in so splendid a manner by the genius of Watt, and which has been so wonderfully productive in good to mankind.

Without going into any details as to its history, we shall only name the English engineers, Cubitt and Brunell, who, in 1851–4, first applied compressed air in its statical application to the sinking of bridge caissons, the Genoese Professor, M. Collodon, who, in 1852, first conceived and suggested the idea of employing it in the proposed tunneling of the Alps; and, finally, the distinguished French engineer, Lommeiller, who first practically realized and applied Collodon's idea in the boring of the Mt. Cenis Tunnel.

II.

ITS APPLICATIONS AND ITS FUTURE.

The applications of compressed air are very numerous, its most important one

being the transmission of power by its means.

Custom has confined the term "transmission of power" to such devices as are employed to convey power from one place to another, without including organized machines through which it is directly applied to the performance of work.

Power is transmitted by means of shafts, belts, friction-wheels, gearing, wire-rope, and by water, steam and air. There is nothing of equal importance connected with mechanical engineering in regard to which there exists a greater diversity of opinion, or in which there is a greater diversity of practice, than in the means of transmitting power. Yet in every case it may be assumed that some particular plan is better than any other, and that plan can be best determined by studying, first, the principles of the different modes of transmission and their adaptation to the special conditions that exist; and, secondly, precedents and examples.

For transmitting power to great distances, shafts, belts, friction-wheels and gearing are clearly out of the question. The practical incompressibility and want of elasticity of water, renders the hydraulic method unfit for transmitting regularly a constant amount of power; it can be used to advantage only where motive power, acting continuously, is to be accumulated and applied at intervals, as for raising weights, operating punches, compressive forging and other work of an intermittent character, requiring a great force acting through a small distance.

Whether steam, air or wire-rope is to be made the means of transmitting power from the prime-mover to the machine, depends entirely upon the special conditions of each case. In carrying steam to great distances very importannt losses occur from condensation in the pipes; especially during cold weather. The wear and tear of cables lessen the advantages of the telodynamic transmission; steep inclinations and frequent changes of direction of the line of transmission often exclude its adoption; while it is entirely excluded when it is rather a question of distributing a small force over a large number of points than of concentrating a large force at one or two points.

Compressed air is the only general mode of transmitting power; the only one that is always and in every case possible, no matter how great the distance nor how the power is to be distributed and applied. No doubt as a means of utilizing distant, yet hitherto unavailable sources of power, the importance of this medium can hardly be overestimated.

But compressed air is also a *storer* of power, for we can accumulate any desired pressure in a reservoir situated at any distance from the source, and draw upon this store of energy at any time; which is not possible either in the case of steam, water or wire-rope.

Larger supply-pipes are required for steam or water transmission; the inconveniences resulting from hot steam pipes, the leakages in water pipes, the high velocities required in telodynamic transmission are all without their counterparts in compressed air transmission. Compressed air is furthermore independent of differences of level between the source of power and its points of application, and is perfectly applicable no matter how winding and broken the path of transmission.

But especially is compressed air adapted to underground work. Steam is here entirely excluded, for the confined character of the situation and the difficulty of providing an adequate ventilation, render its use impossible; compressed air, besides being free from the objectionable features of steam, possesses properties that render its employment conducive to coolness and purity in the atmosphere into which it is exhausted. The boring of such tunnels as the Mt. Cenis and St. Gothard would have been impossible without it. Its easy conveyance to any point of the underground workings; its ready application at any point; the improvement it produces in the ventilating currents; the complete absence of heat in the conducting pipes; the ease with which it is distributed when it is necessary to employ many machines whose positions are daily changing, such as hauling engines, coal-cutting machines and portable rock-drills; these, and many other advantages, when contrasted with steam under like conditions, give compressed a value which the engineer will fully appreciate.

There is every reason to believe that

compressed air is to receive a still more extensive application. The diminished cost of motive power when generated on a large scale, when compared with that of a number of separate steam engines and boilers distributed over manufacturing districts, and the expense and danger of maintaining an independent steam power for each separate establishment where power is used, are strong reasons for generating and distributing compressed air through mains and pipes laid below the surface of streets in the same way as gas and water are now supplied. Especially in large cities would the benefits of such a system be invaluable; no more disastrous boiler explosions in shops filled with hundreds of working men and women; the danger of fire greatly reduced; a corresponding reduction in insurance rates; an important saving of space; cleanliness, convenience and economy. We say economy! For there is no doubt that a permanently located air-compressing plant, established on a large scale, and designed on principles of true economy and not with reference to cheapnes of construction, would supply power at a much less cost than is supposed. Besides, there are many natural sources of power, as water power, which could by this means be utilized, and their immense stores of energy conveyed to the great centers of business and manufacture.

As affording a means of dispensing with animal power on our street railroads, compressed air has been proposed as the motor to drive our street cars. It has already met with some success in this direction, and, to-day, there are eminent French, English and American engineers at work upon this interesting problem.

The compressed air locomotives of M. Ribourt, now in use at the St. Gothard Tunnel, give very satisfactory results. They are compact, neat and comparatively economical.

Compressed air is also applied in a variety of other ways; in signaling, in propelling torpedo boats; in ventilating large and confined spaces; in driving machinery in confined shops; in sinking bridge caissons. The pneumatic dispatch system, the air brake, the pneumatic elevator and hoist are further examples of its use.

CHAPTER I.

The Conditions Modifying Efficiency in the Use of Compressed Air.

I.

LOSS OF ENERGY.

What is at present required in the use of compressed air is a considerable diminution in the first cost of obtaining it by really improving the compressor, and a practical means of working it at a high rate of expansion without the present attendant losses. In the best machines in use at the present day, the *useful effect*, that is, the ratio of the work done by the air to that done upon it, is very small. The losses are chiefly due to the following causes:

1. The compression of air develops heat; and as the compressed air always cools down to the temperature of the surrounding atmosphere before it is used, the mechanical equivalent of this dissipated heat is work lost.

2. The heat of compression increases the volume of the air, and hence it is necessary to carry the air to a higher pressure in the compressor in order that we may finally have a given volume of air at a given pressure, and at the temperature of the surrounding atmosphere. The work spent in affecting this excess of pressure is work lost.

3. The great cold which results when when air expands against a resistance, forbids expansive working, which is equivalent to saying, forbids the realization of a high degree of efficiency in the use of compressed air.

4. Friction of the air in the pipes, leakage, dead spaces, the resistance offered by the valves, insufficiency of valve-area, for workmanship and slovenly attendance, are all more or less serious causes of loss of power.

The question now is, how can we get rid of these losses and obtain a higher efficiency?

The first cause of loss of work, namely, the heat developed by compression, is entirely unavoidable. The whole of the mechanical energy which the compressor-piston spends upon the air is converted into heat. This heat is dissipated by conduction and radiation, and its mechanical equivalent is work lost. The compressed air, having again reached

thermal equilibrium with the surrounding atmosphere, expands and does work in virtue of its *intrinsic energy*.

We proceed to the second loss, which is the work done in driving the compressor-piston against the increase of pressure due to the heat of compression. Since the temperature increases more rapidly than it ought, according to Boyle's law, the work necessary to compression is greater than if the temperature were to remain constant.

The theoretical efficiency of the compressing and working cylinders, as given further on by eq. (486), is:

$$E=\frac{\theta_0}{T_1},$$

where T_1 is the absolute temperature of the air at its exit from the compressor, and θ_0 the absolute temperature at its entrance into the working cylinder, which in practice is that of the surrounding atmosphere. Hence we can increase the value of this fraction only by decreasing the denominator T_1, that is the final heat of compression. This can only be done by abstracting the heat during compression, or by using very low pressures. But low pressures are excluded by other considerations. The weight of air, w, needed per second to perform a given amount of work would have to be considerably increased, and this would necessitate larger pipes, larger cylinders, and would result in a cumbrous and expensive arrangement.

The only remaining alternative, therefore, is to bring about in the compressor the cooling which the air now undergoes after having left it. Table VII shows respectively the portion of work lost when the air is not cooled in the compressor and that lost when it is completely cooled, and will make manifest the advantage there is in cooling. For a pressure of six atmospheres the work spent in isothermal compression to that spent in adiabatic compression is as 3 to 4; and this ratio decreases rapidly as the pressure increases.

II.

METHODS OF COOLING.

There are three methods in which cold water is applied to cool the air during its compression:

1. In case of the so-called hydraulic piston or plunger compressors, the air is over and in contact with a column of water which acts upon the air like an ordinary piston, its surface rising and falling with the backward and forward motion of the plunger. It is obvious that the cooling effect of this large mass of water is very small. There is nothing but surface contact, and water possesses in a slight degree only, the property of conducting, through its mass, heat received on its surface. But we obtain all the advantages there are in having the air completely saturated with water-vapor during its compression, as well as all the disadvantages of having saturated compressed air to work with. What has been here said of hydraulic plunger-compressors, applies equally to hydraulic or ram compressors (first used by Sommeiller at Mt. Cenis, but now obsolete).

2. By flooding the external of the cylinder, and sometimes also the piston and piston-rod. This method of cooling presents neither the advantages nor disadvantages incident to direct intercontact between the air and water; it is that generally adopted in American practice, especially where it is necessary to expose the air-pipes to the out-door atmosphere of winter. The cooling which it effects is, however, only an approach to that which insures the highest efficiency.

3. By injecting into the compressor cylinder a certain quantity of water in a state of the finest possible division, *i. e.*, in the form of *spray*. This method of cooling was first applied by Prof. Collodon in the compressors used at the St. Gothard Tunnel. It is by far the most rational, complete and effective. In this fine state of division the water has many more points of contact with the air, which is both completely cooled and kept thoroughly saturated during compression. It is extremely important that the quantity of water injected into the compressor be a minimum, and hence the weight required for different tensions is given in a table further on.

III.

CONDITIONS MOST FAVORABLE TO ECONOMY IN THE USE OF COMPRESSED AIR.

By working air at full pressure we avoid the formation of ice in the pipes and exhaust ports, not so much because the air is less cooled (for the great fall

of temperature produced by the sudden expansion at the instant of exhaust is almost equal to that produced by interior expansion), but because the air in exhausting requires a high velocity, and this opposes the deposit of ice crystals by its purely mechanical effect, and by the heat developed by its friction.

But even at full pressure we cannot work with high tensions without serious drawbacks. In England, several trials were made at the Govan Iron Works and other places to use air under tensions of eight and nine atmospheres, but they were forced to return to low pressures, owing to the entire arrest of the machine from the formation of ice in the ports. Hence, not taking into account the fact that the useful effect decreases as the pressure increases, we conclude that it is not good practice, even at full pressure, to work with a tension much over four atmospheres, unless we employ special means to reheat the working air.

But while by working at full pressure with moderate tensions, we avoid the inconveniences of very low temperatures, the efficiency obtained is also very low. Notwithstanding this, even up to the present time air is almost exclusively worked at full pressure, especially in the United States. This is because the great cold produced by expansive working has made its adoption impossible. With a cut-off at $\frac{1}{2}$ stroke the temperature of the air falls 71° C, and at $\frac{1}{5}$ cut off 140° C.

Now, to avoid these low temperatures, is is necessary either that the initial temperature of the compressed air be raised by heating it before its introduction into the working cylinder, or that the cylinder in which it expands be heated, or that the compressed air be supplied with heat directly during its expansion by means of the injection of hot water.

In 1860, M. Sommeiller, in order to utilize expansion, heated his working cylinders at Bardonnêche by means of a current of hot air circulating around the cylinders in small pipes. By this means he was enabled to cut off at $\frac{2}{5}$ stroke.

In 1863, M. Devillez recommended that the cylinder be placed in a tank through which hot water was to circulate. Other devices were to place the cylinder into a tank of water, into which from time to time fresh supplies of quicklime were to be thrown. Waste cotton, soaked in petroleum, was also used to heat the working cylinder.

Finally, in 1874, Mr. C. W. Siemens proposed the injection of hot-water into the compressed-air engine cylinder to keep the temperature of the expanding air from falling below the freezing point, just as we inject cold water into the compressor cylinder to prevent a great rise of temperature during compression. This is by far the most efficient mode of supplying heat to the expanding air. Expansion is made completely practicable, and hence the efficiency of the engine is greatly increased, as was shown by M. Cornet, who was the first to apply Mr. Siemens' plan and to prove conclusively its great practical utility.

The quantities of hot water to be injected into the cylinder should always be a minimum; they are given in a table further on.

IV.

EFFICIENCY ATTAINED IN PRACTICE.

It is desirable to know what efficiencies have been attained in practice—of compressors, of compressed-air engines, and of the two machines together as a system.

1. By efficiency of compressor is meant the ratio of the effective work spent upon the air in the compressor to that developed by the steam in the driving engine; or if you choose the resistance divided by the power.

a. In compressors without piston or plunger, such as the hydraulic compressor of Sommeiller, the efficiency is always less than .50. These machines are interesting on account of their simplicity, but their useful effect is always very small.

b. In the so-called hydraulic piston, or plunger-compressor, an efficiency of .90 has been obtained when working at a low piston-speed to pressures of four and five atmospheres.

c. The compressors of Albert Schacht at Saarbrücken, in which the cooling is wholly external, have shown an efficiency of .80 when compressing to a tension of 4 effective atmospheres.

d. Prof. Collodon's compressors, into which water is injected in the form of spray, and which were run at a piston-speed of 345 feet, and compressed the air to an absolute tension of 8 atmos-

pheres, gave an efficiency which never descended below .80, while the temperature of the air never rose higher than 12 to 15 degrees C.

2. The efficiency of compressed-air engines is the ratio of the work which they actually do to that which is theoretically obtainable from the compressed air. The following are examples of its value as found by experiment:

At the Haigh Colliery, Eng., .70
" " Ryhope " " .66

M. Ribourt has found for his locomotives .50 to .60.

In general it may be said that in the very best machines we can count upon from .70 to .75; while in the ordinary ones, working against a variable resistance, this efficiency descends to .50 and .55.

3. The efficiency of the whole system together, that is, the ratio of the work measured on the crank-shaft of the compressed-air engine, to that done by the prime mover, is found to be about .20 to .25 high pressures, and from .35 to .40 for low pressures.

Experiments made at Leeds show a net efficiency of .255 when working with 2.75 effective atmospheres pressure, and .455 when with 1.33 effective atmospheres pressure.

At the Blanzy mines, M. Graillot has found for a final efficiency, .22 to .32 of the effective work of the steam.

M. Ribourt, by experimenting on the new compressed-air locomotives built for the St. Gothard Tunnel, found that the ratio of the tractive effort developed to the original power, (in this case a head of water), was .23; that is, after passing the turbine, the compressor, the expansion regulator, and the cylinders of the locomotive, there remained .23 of the original power.

V.

THE EFFICIENCY OF FULL PRESSURE AND OF EXPANSION COMPARED.

Let W_1 be the work spent upon the air in the compressor:

W_2 the work which the compressed air is theoretically able to do; then its theoretical efficiency will be $\frac{W_2}{W_1}$.

If W=the actual work done by the prime mover, and W' the actual work done by the air, then the real efficiency will be $\frac{W'}{W}$.

Now in the ordinary conditions of practice we know that W_1 is at best .70 W, and W' is only about .70 W_2; hence

$$E'=\text{real efficiency}=\frac{W'}{W}=\frac{.70W_2}{\frac{W_1}{.70}}=.49\frac{W_2}{W_1}=.49E.$$

The value of $\frac{W_2}{W_1}$ (=E=the theoretical efficiency) is .55 for full pressure and .75 for complete expansion. Hence, substituting these values of E above, we find for these two cases a final efficiency of .27 and .37.

VI.

LOSSES OF TRANSMISSION.

The losses due to transmission are calculated further on.

At the works for excavating the Mt. Cenis Tunnel the supply of compressed air was conveyed in cast iron pipes 7⅝ inches in diameter. The loss of pressure and leakage of air, from the supply pipes, in a length of *one mile and fifteen yards*, was only 3½% of the head; the absolute initial pressure was 5.70 atmospheres and it was reduced to 5.50 atmospheres, whilst there was an expenditure at the rate of 64 cubic feet of compressed air per minute. In the middle of the tunnel, through a length of pipe of 3.8 miles, the absolute pressure fell only from six atmospheres to 5.7 atmospheres, or to .95 of the original pressure.

At the Hoosac Tunnel the air was carried through an 8-inch pipe from the compressors to the heading, a distance of 7,150 feet, operating six drills, with an average loss of *two* pounds pressure.

CHAPTER II.

THE PHYSICAL PROPERTIES AND LAWS OF AIR.

I.

INTRODUCTORY.

A fluid is *a body incapable of resisting a change of shape.* Fluids are either liquids, vapors or gases. Water may be taken as the type of the first; steam is the type of all vapors, and air of all gases.

Gases are either *coercible* gases, *i. e.*,

such as under ordinary circumstances may be condensed into liquids or even solids, as CO_2; or *permanent* gases, which retain their aëriform state under all ordinary circumstances of temperature and pressure. This distinction is convenient. Air has been condensed, but certainly not under *ordinary* circumstances.

Air then is a *permanent* gas, and may be considered a *perfect fluid;* that is,

1. It is incapable of experiencing a distorting or tangential stress, its molecules offering no resistance to relative displacement among themselves; hence no internal work of displacement need be considered.

2. It has the power of indefinite expansion so as to fill any vessel of whatever shape or size.

3. It exerts an equal pressure upon every point of the walls of the vessel enclosing it.

4. It is of the same density at every point of the space it occupies.

II.

BOYLE'S LAW.

This law states that the temperature being constant, the volume of a gas varies inversely as the pressure, &c., formulated,

$$pv' = p_0 v_0 \qquad (1)$$

Where v_0 = the volume of a given weight of the gas at freezing temperature and a pressure p_0; and v' = the volume of the same weight of gas at the same temperature and at any pressure p.

Dry air, a mechanical mixture of oxygen and nitrogen, being a permament gas, obeys this law.

III.

THE LAW OF GAY-LUSSAC.

This second law of gases may be stated thus: The volume of a gas under constant pressure expands when raised from the freezing to the boiling temperature, by the same fraction of itself, whatever be the nature of the gas formulated:

$$v = v^1 (1 + a_1 t) \qquad (2)$$

It has been found by the careful experiments of M. M. Rudberg, Regnault and Prof. Balfour Stewart and others, that the volume of air at constant pressure expands from 1 to 1.3665 between 0° C. and 100° C. Hence for a variation in temperature of 1° C., the volume varies by .003665 or $\frac{1}{273}$ of the volume which the air occupied at 0° C. and under the assumed constant pressure. In equation (2) the coefficient a, is therefore equal to $\frac{1}{273}$.

IV.

BOYLE'S AND GAY-LUSSAC'S LAW.

Combining the equation formulating Boyle's law with that formulating Gay-Lussac's, we obtain,

$$pv = p_0 v_0 (1 + a_1 t) = p_0 v_0 a_1 \left(\frac{1}{a_1} + t\right);$$

or letting $a = \frac{1}{a_1} = 273$, we have

$$pv = \frac{p_0 v_0}{a}(a + t) = \text{R}\,(a + t) \qquad (3)$$

This last equation is a general expression for both Boyle's and Gay-Lussac's law, and completely expresses the relation between temperature volume and pressure.

R is a constant and depends upon the density of the gas. Its value for atmospheric air is determined as follows:

The weight of the standard unit of volume of a substance in any condition is the *specific weight* of that substance in that condition.

The *specific weight* of air, that is to say, the weight of a cubic foot of air at 0°C. and under a pressure of 29.92 inches of mercury, is according to M. Regnault .080728 lbs. avoirdupois.

The *specific volume* of a gas is the volume of unit of weight; it is the reciprocal of the specific weight.

The *specific volume* of air, *i.e.*, the volume in cubic feet of one pound avoirdupois at 0° C. and under the pressure of 29.92 inches mercury is:

$$v_0 = \frac{1}{.080728} = 12.387 \text{ cubic feet.}$$

Let $p_0 = 2116.4$, the mean atmospheric pressure in lbs. per square foot. Then

$$\text{R} = \frac{p_0 v_0}{a} = \frac{2116.4 \times 12.387}{273} = 96.0376.$$

V.

ABSOLUTE TEMPERATURE.

Making $t = -273$ in the equation

$$pv = \text{R}(a + t)$$

the second member reduces to zero, and hence

$$pv = o.$$

The distance of the freezing point from the bottom of the tube of an air thermometer is to the distance of the boiling point from the bottom as 1:1,3665. Hence, in the centigrade scale, where the freezing point is marked 0° and the boiling point 100°, the bottom of the tube will be marked—272°.85.. The lowest reading of the scale is, therefore, —273°. If this reading could be observed it would imply that the volume of the air had been reduced to nothing. This is evidently a purely theoretical conception, but in dealing with questions relating to gases it is exceedingly convenient to reckon temperatures, not from the freezing point but from the bottom of the tube of an airthermometer. *Absolute zero*, therefore, is marked $-273°$ on the Centrigrade scale (corresponding to $-459.°4$ on the Fahranheit's scale) and is the temperature at which all molecular motions cease, and the mechanical effect, which we call pressure, and which is due to these motions, becomes zero.

VI.

LAW OF THE PRESSURE, DENSITY AND TEMPERATURE.

Let D_0=the density of a weight w of air at the temperature 0° C. and under the pressure p_0, v_0 being the corresponding volume;

D=its density at pressure p, temperature t, v being its corresponding volume;

D′=its density at temperature 0° C. pressure p and volume V′.

We shall have

$$D = \frac{w}{v},$$

or by taking w=unity,

$$D = \frac{1}{V}, \text{ and } v = \frac{1}{D}.$$

Placing this value of v in equation (1) we get

$$\frac{p}{p_0} = \frac{D'}{D_0}; \qquad (4)$$

that is, the pressure of a gas is proportional to its density.

From (2) we have,

$$\frac{D}{D'} = \frac{1}{1+a't} = \frac{a}{a+t}; \qquad (5)$$

That is, the density of a gas is inversely as its temperature, the latter being reconed from absolute zero.

Combining equations (4) and (5),

$$\frac{D}{D_0} = \frac{p}{p_0} \times \frac{a}{a+t}, \text{ or}$$

$$p = \frac{p_0}{D_0} \times \frac{a+t}{a} D. \qquad (6)$$

But $D = \frac{w}{v}$, and hence

$$pv = \frac{p_0}{D_0} \times \frac{(a+t)}{a} w \qquad (6a)$$

(6) shows that the density of a gas is:

At constant temperature, directly as the pressure;

At constant pressure, inversely as the absolute temperature.

$\frac{p_0}{D_0}$=constant for any given gas. For air $\frac{p_0}{D_0} = \frac{2116.4}{.080728} = 26216.43$ (according to Rankine, 26214); this is the height in feet of a column of fluid of density D_0, which produces a pressure p_0 pounds per square foot of surface; letting H be this height, the weight of the column having one square foot for its surface will be D_0H, or

$$D_0 H = p_0.$$

If in ($6a$) we make v=1, we get

$$w = \frac{p}{a+t} \times \frac{Da}{p_0} = \frac{p}{a \times t} \times \frac{1}{R} \qquad (7)$$

which is the weight of unit of volume, or the *specific weight* of air.

Making w=1 in same equation, we have for the volume of unit of weight,

$$v = \frac{p_0}{D_0 a} \times \frac{a+t}{p} = R\frac{a+t}{p} \qquad (8)$$

called the *specific volume*. (7) and (8) are rciprocals of each other.

VII.

THE MEASUREMENT OF HEAT.

Any effect of heat may be used as a means of measuring it, and the quantity of heat required to produce a particular effect is called a thermal unit. It has been found best to take a thermal unit to be the quantity of heat which corresponds to some definite interval of temperature in a definite weight of a particular substance.

Def. A *British Thermal Unit* is the quantity of heat which corresponds to an interval of one degree of Fahrenheit's scale, in the temperature of one pound of pure liquid water at its temperature of greatest density (39° 1 Fahr).

Def. A *Calorie*, or French Thermal Unit, is the quantity of heat which corresponds to the *Centigrade* degree in the temperature of one *kilogram* of pure liquid water, at its temperature of greatest density, (3° 94 C.).

Def. The *Specific Heat* of a body, is the ratio of the quantity of heat required to raise that body one degree, to the quantity required to raise an equal weight of water one degree.

It has been proven for permanent gases, that,

1. The specific heat is constant for any given gas, and is independent of the temperature and pressure;

2. The thermal capacity per unit of volume, is the same for all simple gases when at the same pressure and temperature;

3. The specific heat increases with the temperature, and probably with the pressure, when the gas is brought near the point of liquifaction, and no longer obeys Boyle's law.

The above three conclusions are true of specific heat at *constant volume*, as well as of specific heat at *constant pressure*, as far as regards simple gases and air, (which, being a mechanical mixture, obeys the same laws as simple gas).

It was shown by Laplace, that the specific heat of a gas is different, according as it is maintained at a constant *volume*, or at a constant *pressure*, during the operation of changing its temperature.

The specific heat of gases was independently determined by M. Regnault and Prof. Rankine; experimentally by the former, and theoretically by the latter. Their results agreed exactly, and are those now generally accepted. As given in Watt's Dictionary of Chemistry,

The specific heat at constant pressure is .238

As we shall find farther on, the specific heat at constant volume is .169.

$$\therefore \frac{c}{c^1} = \frac{.238}{.169} = 1.40 = r$$

CHAPTER III.

Thermodynamic Principles and Formulas.

I

INTRODUCTORY.

It is well known that the cylinder of an air compressor becomes very hot even at a low piston-speed. This fact brings us face to face with the doctrine of the conversion of energy; for it is the conversion of the visible, mechanical energy of the piston into that other invisible form of energy called heat. Thus we see we are at the very outset confronted with a thermal phenomenon, whose consideration involves the science called thermodynamics. To begin with we had no other but the visible mechanical energy of a moving piston; but very soon sensible heat manifests itself, and this heat can be developed only at the expense of part at least, of the energy of the moving piston.

These phenomena are referable to the two general principles which form the basis of the science of thermodynamics, viz :

1. All forms of energy are convertible.

2. The total energy of a substance or system cannot be altered by the mutual actions of its parts.

* "The conversion of one form of energy into another takes place with as great certainty and absence of waste, and with the same integrity of the elementary magnitude as the more formal conversion of foot-pounds in kilogrammeters." "In the development of the axioms that nothing is by natural means creatable from nothing, and that things are equal to the same thing only which are equal to each other, and in the application to them of empirical laws with reference to the behavior of bodies under the action of heat and mechanical effect" consists chiefly the science of thermodynamics.

The general equation of thermodymamics which expresses the relation between heat and mechanical energy under all circumstances, was arrived at independently in 1849 by Professors Clausius and Rankine. The consequences of

* "History of Dymamical Theory of Heat," by the late Porter Poinier, M.E., in *Popular Science Monthly* for January, 1878.

that equation have since been developed and applied by many distinguished writers.

Of course we shall here confine ourselves to so much only of the Mechanical Theory of Heat as is necessary to an intelligent comprehension of our subject in doing so, and shall follow in outline the treatment given by M. Pochet, in his admirable "*Nouvelle Méchanique Industrielle*," making free use, at the same time, of the works or Zeuner, Rankine and Clausius.

II.

HEAT AND TEMPERATURE.

Heat denotes a motion of particles on a small scale just as the rushing together of a stone and the earth denotes a motion on a large scale, a mass motion. It is due to a vibratory motion impressed upon the molecules of a body. The more rapid the vibrations the more intense the heat. The quantity of heat in a substance could be measured by multiplying the kinetic energy of agitation of a single molecule by the number of molecules in unity of weight, supposing the substance to be homogeneous and the heat uniformly distributed. Thus the thermometer and dynamometer reveal to us phenomena which are in reality identical, and we can establish a measuring unit to which both effects can be referred.

Temperature is the property of a body considered with reference to its power of heating other bodies. It is a function of the variables, volume and pressure, or,

$$t = \rho \ (v, p)$$

that is, all bodies having the same pressure and volume have the same temperature. This is expressed by the differential equation:

$$dt = \left(\frac{dt}{dp}\right)dp + \left(\frac{dt}{dv}\right)dv, \qquad (9)$$

where $\left(\frac{dt}{dp}\right)$ and $\left(\frac{dt}{dv}\right)$ are the partial differential co-efficients, dt in the former denoting the increment of t when, v remaining constant, p alone is increased by dp; and in the latter, the increment received by t when p remaining constant, v is increased by dv; whilst in the first number of the equation, dt represents the *total* increment of t due to the simultaneous reception by p and v of the increments dp and dv, respectively.

III.

THE TWO LAWS OF THERMODYNAMICS.

The whole mechanical theory of heat, rests on two fundamental theories: *

1. That of the equivalence of heat and work; whensoever a body changes its state in producing exterior work, (positive or negative), there is an absorption or disengagement of heat in the proportion of one British thermal unit for every 772 foot pounds of work, (or of one French thermal unit for every 423.55 kilogrammeters of work).

This mechanical equivalent of heat was first *exactly* determined by Mr. Joule, in honor of whom it is called Joule's equivalent, and is denoted by the symbol J.

2. The theorem of the equivalence of transformations; when a body is successively put in communication with two sources of heat, one at a higher temperature t, the other at a lower temperature t_0, its temperature remaining constant and equal to that of each source during the whole time of contact, and the body neither receiving nor losing heat except by reason of its contact with the two sources, the ratio of the quantity of heat Q given out by the higher source to the quantity Q^1 transferred to the lower source, is independent of the nature of the bodies; it depends only on the temperatures, t and t_0, of the two sources.

Clausius states this as follows: In all cases where a quantity of heat is converted into work, and where the body effecting this transformation ultimately returns to its original condition, another quantity of heat must necessarily be transferred from a warmer to a colder body; and the magnitude of the last quantity of heat, in relation to the first, depends only on the temperature of the bodies between which heat passes, and not upon the nature of the body effecting this transformation; or, more briefly, heat cannot *of itself* pass from a colder to a warmer body.

IV.

HEAT AND MECHANICAL ENERGY.

The quantity of heat which must be imparted to a body during its passage, in a given manner, from one condition to another, (any heat withdrawn from the

* See Clausius on Heat, Memoir.

body being counted an important negative quantity) may be divided into three parts, viz :

1. That employed in increasing the heat actually existing in the body;
2. That employed in producing interior work.
3. That employed in producing exterior work.

The first and second parts, called respectively the *thermal* and *ergonal* content* of the body, are independent of the path pursued in the passage of the body from one state to another; hence both parts may be represented by one function, which we know to be completely determined by the initial and final states of the body. The third part, the equivalent of exterior work, can only be determined when the precise manner in which the changes of condition took place is known.

Let dQ=the element of heat absorbed during an infinitesimal change of condition;

U_0=the free heat present in the body at the beginning, *i.e.*, the body's intrinsic energy;

U=the free heat present in the body at the end of the change, plus the heat consumed by internal work during the change of state;

pdv will be the work accompanying the passage of the body from a state (p_1v) to a state $(p+dp, v+dv)$;

Then the heat spent while the body passes from one temperature t to another $t+dt$, and from one state (p_1v_1) to another $(p+dp, v+dv)$ will be :

$$dQ=(U-U_0)+\frac{1}{J}.pdv,$$

$$=dU+\frac{1}{J}.pdv; \qquad (10)$$

where du depends upon the *initial* and *final* circumstances, while $\frac{1}{J}.pdv$ depends on the intermediate circumstances of the change of state.

We can write $du=o$ and entirely exclude interior work and heat by confining ourselves to *cyclical processes*, that is to say, to operations in which the modifications which the body undergoes are so arranged that the body finally returns exactly to its original condition, the interior work, positive and negative, exactly neutralizing each other.

$$u=f\ (p, v),$$

that is, the internal heat of a body depends only upon the volume of the body, and the pressure to which it is subjected. Hence the increase of internal heat when the body passes from a state (p, v) to a state $(p+dp, v+dv)$ will be:

$$du=\left(\frac{du}{dp}\right)dp+\left(\frac{du}{dv}\right)dv \qquad (11)$$

Substituting in equation (10) the value of du as given by equation (11), we have

$$dQ=\left(\frac{du}{dp}\right)dp+\left\{\left(\frac{du}{dv}\right)+\frac{p}{J}\right\}dv \qquad (12)$$

an equation which is not integrable; since this would require that the second derivatives of the co-efficients of dp and dv (which are, respectively, $\frac{d^2u}{dp.dv}$ and $\frac{d^2u}{dv.dp}+J$) should be equal to each other*; this would imply the impossible condition $J=o$. That is, mechanically speaking, the quantity of heat passing cannot be expressed as a function of the initial values of p and v. The equation can only be integrated when we have a relation given, by means of which t may be expressed as a function of v, and therefore p as a fnnction of v alone. It is this relation which defines the manner in which the changes of condition take place; the quantity of heat passing depends upon the *intermediate* circumstauces of change of state, circumstances which may be anything.

When a body is heated from a temperature t to another $t+dt$, preserving the *same volume*, no external work will be done and $dv=o$. Hence eq. (12) will become:

$$dQ=\left(\frac{du}{dp}\right)dp$$

$$=c_1\ dt \qquad (13)$$

which, by definition, is the specific heat at constant volume.

The above equation gives:

$$\frac{du}{dp}=c_1\left(\frac{dt}{dp}\right) \qquad (13a)$$

* Clausius on Heat. Memoir.

* See Ray's Infinitesimal Calculus, p. 366; also McCullough on Heat, arts. 61 and 62.

the partial differential co-efficient of t with respect to p.

If the body passes from t to $t+dt$ under *constant pressure*, $dp=o$, and hence (12) becomes:

$$dQ=\left\{\left(\frac{du}{dv}\right)+\frac{p}{J}\right\}dv=c\,dt \qquad (14)$$

which, by definition, is the specific heat at constant pressure.

From (14) we have:

$$\left(\frac{du}{dv}\right)+\frac{p}{J}=c\left(\frac{dt}{dv}\right). \qquad (14a)$$

Substituting these values of the partial derivatives in eq. (12), we obtain a second expression for dQ, viz.:

$$dQ=c_1\left(\frac{dt}{dp}\right)dp+c\left(\frac{dt}{dv}\right)dv \qquad (15)$$

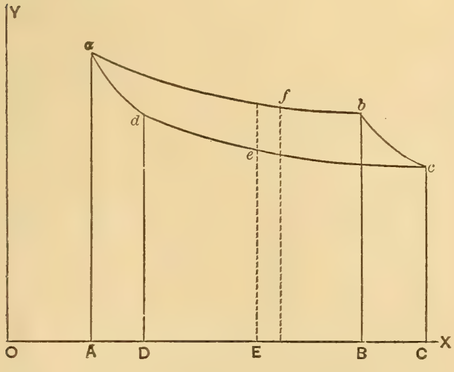
It is convenient to have this equation in a form involving only the temperature and specific heats, and not the quantity Q. We obtain such a form by differentiating (13a) with respect to v, and (14a) with respect to p and subtracting the first result from the second. The form obtained is:

$$\frac{1}{J}=(c-c_1)\frac{d^2t}{dv.dp}+\left(\frac{dc}{dp}\right)\left(\frac{dt}{dv}\right)-\left(\frac{dc_1}{dv}\right)\left(\frac{dt}{dp}\right) \qquad (16)$$

V.

THE DIFFERENTIAL EQUATION OF THE SECOND PRINCIPLE.

In the figure,



1. Let OA=the initial volume of a body whose temperature is t; it expands in contact with a source of heat, (isothermally), from volume OA to volume OB, when its temperature is then still t.

Q=the quantity of heat supplied by the source;

2. It is now left to expand adiabatically, *i.e.*, without the addition or subtraction of heat, from volume OB to volume OC, when its temperature will have fallen to t_0;

3. Now place it in contact with a source of heat of the same temperature t_0, and compress it from OC to OD, when its temperature is still t_0.

Q^1=the quantity of heat that has passed into the source;

4. Compress it adiabatically from volume OD to volume OA, when its temperature will again be t; the body has now undergone a *complete cycle*, during which it has evidently done work represented the area $abcd$; hence,

$Q-Q^1$=heat disappeared, and from the first law of thermodynamics,

$$Q-Q_1=\frac{1}{J}\times abcd=\frac{1}{J}\times A. \qquad (17)$$

Now the second law of thermodynamics states that Q and Q^1, (the heat received and the heat given out), are independent of the nature of the bodies, and dependent only upon the temperature.

Suppose that the difference of temperature of the two sources of heat is infinitely small, t and $t+dt$. Also consider t and v as the independent variables determining the state of the body, $p=f(v, t)$.

A, in the above equation, is the integral between v_0 and v of the elementary areas, such as ef. Now if E$e=p$, Ef is what p will become when the volume remains constant, and the temperature takes an increment dt; fe therefore measures the differential increment

$$\left(\frac{dp}{dt}\right)dt,$$

where $\frac{dp}{dt}$=the partial derivative of p with respect to t.

$$\text{Hence, } Q-Q'=A.\frac{1}{J}=\frac{1}{J}\int_{v_0}^{v}\left(\frac{dp}{dt}\right)dtdv$$
$$=\frac{1}{J}dt\int_{v^0}^{v}\left(\frac{dp}{dt}\right)dv,$$

taking the independent variable dt out of the integration symbol.

Q is the heat supplied to keep at t the

temperature of the body expanding from v_0 to v, and, therefore,

$Q=\rho(t,v_0,v$; the nature of the bodies);

also,

$$Q'=F''(t,\ v_0,\ v)=F\ (t),$$

the variables v_0, v being implicitly contained in F.

Since $Q=Q'$ when t becomes $t+dt$ we have,

$$Q=F(t+dt)=F(t)+F'(t)\ dt$$

and

$$\frac{Q}{Q_1}=1+\frac{F'(t)}{F(t)}dt.$$

According to the second principle,

$\frac{Q}{Q'}$ is independent of the nature of the bodies; hence,

$$Q-Q'=Q'\frac{F'(t)}{F\ (t)}dt=\frac{1}{J}\ dt\int_{v_0}^{v}\left(\frac{dp}{dt}\right)dv$$

and

$$Q'=\frac{1}{J}\frac{F\ (t)}{F'(t)}\int_{v_0}^{v}\left(\frac{dp}{dt}\right)dv.$$

Now, suppose $v-v_0$ becomes indefinitely small and equal to dv; Q' will become dQ, Q being the heat necessary to keep at t the temperature of a body whose volume increases by dv; hence the differential equation of the first order,

$$dQ=\frac{1}{J}\ \rho\ (t)\frac{dp}{dt}\ dv \tag{18}$$

the differential equation of the second principle.*

Calculation of the function $\rho\ (t)$. It may have several forms. Making $dt=o$ in eq. (9), we get,

$$dp=-\frac{\left(\frac{dt}{dv}\right)}{\left(\frac{dt}{dp}\right)}dv;$$

Placing this value of dp in eq. (15),

$$dQ=(c-c_1)\left(\frac{dt}{dv}\right)dv.$$

Moreover in (9) $\left(\frac{dp}{dt}\right)$ represents the partial derivative of p with relation to t when v is constant; making $dv=o$,

$$\left(\frac{dp}{dt}\right)=\frac{1}{\left(\frac{dt}{dp}\right)};$$

Hence eq. (18) may be written,

$$dQ=\frac{1}{J}\rho(t)\frac{dv}{\left(\frac{dt}{dp}\right)}.$$

Equating this with the value of dQ above, we have,

$$\frac{1}{J}\ \rho\ (t)=(c-c_1)\left(\frac{dt}{dp}\right)\left(\frac{dt}{dv}\right), \tag{19}$$

from which $\rho\ (t)$ may be calculated.

Again, if we take Eq. (16) and suppose it applied to bodies whose specific heats c and c_1 are independent, the first of the pressure and the second of the volume, as is the case in permanent gases, these conditions give $\left(\frac{dc}{dp}\right)$ and $\left(\frac{dc_1}{dv}\right)$ equal to zero, and the equation becomes,

$$(c-c_1)\left(\frac{d^2t}{dpdv}\right)=\frac{1}{J}. \tag{20}$$

Dividing eq. (19) by this we get,

$$\rho(t)=\frac{\left(\frac{dt}{dp}\right)\left(\frac{dt}{dv}\right)}{\frac{d^2t}{dp\ dv}} \tag{21}$$

giving $\rho\ (t)$ as a function of $t\ [=f\ (p,v)]$ and of its partial derivatives.

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* See Zeuner, "Théorie Méchanique de la Chaleur," troisième section, iii.
Also, Clausius on Heat, first Memoir.

Mr. Arnold Hague, the eminent American geologist, has been engaged by the Chinese Government to examine and report upon the mineral resources and mining industry of the Celestial Empire, and sailed from San Francisco on Thursday, the 15th of August, by the steamer Gaelic, to enter upon his duties. He expects to take the field immediately upon arrival, and continue active operations until about the first of December, when he will go into winter quarters. The excellent work performed by Mr. Hague in connection with King's Survey of the Fortieth Parallel, and more recently in Guatemala, is a guarantee of his fidelity and skill in this new undertaking.

RECENT ADVANCES IN THE MANUFACTURE OF IRON AND STEEL, AS ILLUSTRATED IN THE PARIS EXHIBITION.*

By RICHARD AKERMAN, Professor at the School of Mines, Stockholm.

From "The Engineer."

As international exhibitions have of late followed so close on each other, it is natural that the discoveries and inventions that can be made in the interval between each and its successor are not numerous. The technical literature too, especially that which is concerned with the manufacture of iron and steel, has in the last fifteen years been so developed that nearly all improvements are, early after their introduction, found described in a number of periodicals. This has been conspicuously the case since the foundation of the Iron and Steel Institute, which I now have the honor of addressing, and which has been beneficial in so high a degree to that branch of metallurgy to which its attention is more particularly devoted; for at its meetings, as is well known, the most pressing questions affecting the production of iron and steel have been discussed with eminent practical knowledge from every point of view, and many facts highly interesting to the manufacturer, and of which, without intervention of this excellent association, mankind would at most have had but a faint idea, have been, thanks to your "Transactions," disseminated over the whole world. In this connection I must also ask to be allowed to point out another advantage which this association has brought about. Ten years ago there still prevailed at many iron and steel works a very great reluctance to open their doors to strangers, and many an establishment which now willingly admits strangers was then, if not altogether, shut, at least not accessible in the same degree as now. Who can well deny that the opinions expressed by the Institute conducted in a very great degree to bring about this change? And, further, that the facilitated access to iron and steel works has greatly promoted a general knowledge of the latest advances and improvements? A certain result, however, of all this is, that an iron metallurgist, who has properly kept pace with the times, can now scarcely expect that an International Exhibition can produce anything altogether new to him within its walls. Neither for this reason ought it to be required of me, that I should have something new to say to you, even with all the resources of that on the Champs de Mars behind me. Indeed, I would never have entertained the question of making a demand on your precious time, as I now do, if I had not been asked to do so by certain prominent men within this society.

As the leading principle pervading the whole of modern iron manufacture, it must in the first place be pointed out how the cinder-free ingot, iron and steel, is always more and more supplanting the old cinder-mixed wrought iron. This change, as is well known, derives its real origin from the time of Mr. Bessemer's grand invention, which marks an epoch in the history of the iron trade. This important change in the process has also been powerfully assisted by the diminution in the cost of fusing iron and steel, which has been placed within reach by the important application of the so-called regenerative principle by our honored president, Dr. Siemens. For, as we all know, it is not enough that crucible steel can by means of this furnace be made more cheaply, but the Siemens furnace itself has also realised the long-cherished hope of being able, without the help of the costly crucible, to melt steel and iron. Open-hearth metal may be said to have celebrated its baptismal ceremony just at the last Paris Exhibition, when it was named, after its first maker, Martin metal. The Bessemer manufacture, though then ten years old, may be said to have been at the same time in its childhood; and though much railway material of Bessemer metal was shown at that Exhibition, the opinion of its goodness was yet so little established that there were works which, under the common appellation cast steel, sought to conceal that their products were manufactured by the Bessemer process.

* Iron and Steel Institute.

How different is the aspect of affairs to-day, after an interval of only eleven years! Although many a Bessemer works now employs materials inferior to those then used, none seeks any longer to conceal its Bessemer manufacture, but with pride exhibits its Bessemer rails, which, as is well known, are now in process of completely supplanting rails of puddled iron; and one can form some idea of the completeness of the arrangements for rolling Bessemer rails by inspecting the rails from Seraing, 55 metres in length; from Charles Cammell and Co.'s, 43 metres; and Brown, Bayley, and Dixon's rails, 130 feet long, rolled direct from the ingot without intermediate heating. Sweden had, indeed, already, at the Paris Exhibition of 1867, shown the finest razors and other similar wares of Bessemer metal, and in the manufacture of cutlery in Sweden this material is now almost exclusively employed. Styria had likewise then to offer beautiful work of embossed Bessemer metal; but these cases formed at that time rare exceptions, depending on the special goodness of the ores which were employed in the Bessemer manufacture of those countries. For some time Bessemer metal was almost exclusively confined to the manufacture of rails and some other descriptions of railway material. The Exhibition of 1878, on the contrary, affords clear evidence that Bessemer metal is now in most countries employed for purposes for which only a few years ago it was not generally considered sufficiently good. It appears also to have already become very evident that the formerly only too prevailing view that Bessemer metal must necessarily be inferior to other ingot metal only resulted from certain Bessemer works which produced both Bessemer and open-hearth metal, employing for the former more impure materials than for the latter. Where similar materials are used in each case, the ingot metal may be as good from the Bessemer converter as that from other sources. In other words, the quality of the ingot metal is not so much dependent on the methods, Bessemer, Siemens-Martin, or crucible melting, as on the purity of the materials, and the care with which the products are sorted according to their degree of hardness. To sum up here all the purposes for which this Exhibition proves that Bessemer metal has been employed would carry us beyond the compass of this short paper, but it is perhaps right to point out some of them. Thus in the French division, Lobel and Turbot exhibit heavy chains, welded in the common way, made of Bessemer iron from La Société des Forges de Dénain et d'Anzin. In the same way, Ernest Dervaux-Ibled manufactures railway wagon couplings, screw-bolts, and other similar articles of Bessemer iron, from the Bessemer works just named. Further, not only several French makers, such as David, Damoizeau, Doremieux Fils and Cie., and the Société de Commentry Fourchambault, but also Brown, Bayley, and Dixon, of Sheffield, have exhibited heavy Bessemer chains without weld, produced on nearly the same principle as has long been employed for lighter chains, as dog-couplings and such like. La Compagnie des Fonderies, Forges, et Acieries de Saint Etienne exhibits Bessemer rings for cannon. Similar articles, we learn, are also produced at Seraing, whose beautiful display, like several others, as, for instance, those of the Oesterreichische Staats Eisenbahn Gesellschaft in Hungary, and Demidoff in Russia, comprehend good boiler-plate of Bessemer iron. Similar boiler-plate was also exhibited by the West Cumberland Iron and Steel Company, and to give an idea of its good quality, a large hole has, by the help of dynamite, been driven through the middle of the plate without its being possible to see that any portion of the plate has been wrenched away by the violent explosion; for the hole is bounded by edges that have been bent out at right angles, but have not been torn off. Both the evenness and excellent quality of the Bessemer, as well as the Siemens-Martin plate, and the very great superiority of both over plates of puddled iron, are seen most clearly by the exhibit of the Swedish Iron Board (Fercontoret), which shows that the ingot plate, when tested with a falling weight, withstood from five to nine blows from a height of 4.5 metres without the least failure; while the Swedish iron plate only withstood four to six blows of the same weight from a height of only 1·5 metre, or a third of the height in the ingot-plate tests. Further, in these tests, with a falling weight, the buckling be-

fore the least sign of fracture averaged 150 to 160 mm., while the Swedish plate of puddled iron never permitted before fracture greater buckling than 104 mm. Nevertheless, the Swedish iron plate was, as such, of very superior quality, for tests, made with the same falling weight; of best best Staffordshire and best Yorkshire plates showed that the former gave way at the first blow from a height of only 1 metre, while the Yorkshire plate at the utmost withstood three blows from a height of 1.5 metre, and showed in that case a buckling of 68 mm. When the height of fall of only 1.5 metre used for the puddled plates was employed for the ingot plate the latter withstood twenty-five blows, while, on the other hand, the weight at the first blow passed through even the Swedish plate of puddled iron when the fall-height of 4.5 metres used for the ingot plate was also employed for it. Tests were also made for the ingot plate with a fall from a height of up to 9 metres, when it withstood before fracture three blows with the same buckling as in the case of the lower height, also before fracture. Plates of Swedish iron made on the Lancashire hearth, as might have been expected beforehand, appeared in respect to its qualities to lie between those of puddled iron and those of ingots, inasmuch as it was much better than the former, but far inferior to the latter. The ball used as a falling weight in all these tests had a weight of 875 kilogs., spherical in its lower end, and a diameter of 253 mm. The interior diameter of the iron foundation to which the plates were fastened during the tests with thirty-six rivets in a double row was 537 mm. The diameter of the falling weight was thus to the diameter of the part of plate exposed to buckling as 10 to 21. All the plates were 9 mm. thick and 1 metre in diameter.

These experiments, besides, show how enormous is the influence which the content of phosphorus exercises on the power possessed by iron of resisting blows; for the main difference between the chemical composition of the different puddled plates lay in their quantity of phosphorus, for while the Swedish puddled plates contained only 0.016 to 0.021 per cent. of phosphorus the percentage in the Yorkshire plate was 0.094, and in the Staffordshire plate, 0.203. In addition to this difference in the content of phosphorus, there is also in the Staffordshire plate a larger quantity of silicon, or more probably of cinder. No proper difference between Bessemer and Siemens-Martin plates could be discovered in the course of these experiments, which comprehend both complete analyses and tension tests. Yet it almost appears as if the Martin plates have a somewhat greater ductility than Bessemer plate with the same content of carbon. This is also confirmed by the numerous and complete tables of breaking and other tests included in the beautiful exhibit of the Oesterreichische Staats Eisenbahn Gesellschaft. From these it appears to follow that the Bessemer metal made by this company at Reshicza has, in general, a somewhat greater tensile strength, but, at the same time, also less ductility, than Martin metal of corresponding degrees of hardness from the same works. These differences, however, probably depend not so much on the method of production as upon a trifling excess of the contents of phosphorus and silicon in the Bessemer over the Martin metal, made from materials of equally good quality. The Siemens-Martin lends itself more readily than the Bessemer process to the production of large and heavy pieces, inasmuch as there is naturally much less difficulty in simultaneously melting in several large Siemens furnaces, for which no blast is required, that in blowing in at the same time several Bessemer converters. This is also the reason why the Compagnie des Forges et Aciéries de la Marine et des Chemins de Fer, which uses Bessemer metal for its smaller cannon, makes the larger of open-hearth metal. The largest ingot which is to be found in the Exhibition was, probably, from the cause just named, made by the Siemens-Martin process. For Creusot shows in its splendid and well-filled Exhibition pavilion a representation in natural size of an ingot made in this way, weighing 120,000 kilogs. The largest actual ingot which is shown is also made by the same process, and is to be seen in the no less beautiful exhibit of the above-named Compagnie des Forges et Aciéries de la Marine. Siemens-Martin iron is, as is well known, employed to a greater extent than Bessemer for plates, axles, and

other nice purposes, of which also the Exhibition yields such numerous specimens that it is perhaps unnecessary to notice any separate examples. I therefore confine myself to pointing out how, among others, both the above-named works, the Compagnie des Forges et Aciéries de la Marine and des Chemins de Fer and Creusot, use Martin steel for rings and tubes for cannon, and Martin iron for heavy armor plates. John Brown and Co. and Charles Cammel and Co. also exhibit heavy armor plates, consisting partly of ingot iron, for these plates are not exclusively made of it, but consist of about half of puddled and half of ingot iron. The plates are said not to be welded together in the common way of thick puddled and ingot iron laid upon each other, but we learn that the union of the different sorts of iron is brought about at the former works by casting fused iron over a properly-heated puddled iron plate provided with a high iron border, while Cammel makes his double plates by melting down the ingot iron in a furnace whose bottom, so to speak, consists of the puddle iron plate, and then letting them cool together. Both these processes are, of course, finished by rolling. The methods of working just described, as well as the fact before referred to, of Bessemer chains without and with weld, certainly prove the groundlessness of apprehended difficulties in the welding of ingot iron. That heavy armor plates even can be produced of open-hearth metal, by piling and welding together in the way commonly used for puddled iron, is, however, shown by the Compagnie des Forges et Aciéries de la Marine, which, along with its ingot plates, made each of an ingot, also shows an armor-plate 0·56 metre thick, 4·20 metres long, and 1·42 metre broad, weighing 26,500 kilogs. This plate was produced by piling and welding together an anormous number of ingot iron bars. Besides, not only two Swedish exhibits, but also those of the Oesterreichische Staats Eisenbahn Gesellschaft and others afford the clearest evidence that if the ingot metal is only of sufficiently pure quality, it is possible to weld completely, not only the softest qualities, but also very hard Bessemer and Martin metal. The idea of producing armor-plates by piling and welding together ingot iron, instead of making it of a single large ingot, is grounded on the fear that if there be any defect in the ingot, the whole of the plates made from it would thereby be rendered unserviceable, while, on the other hand, when many different layers are welded together, a defect occurring in any of them would not have so great an influence on the plates. The maker of such plates is, in other words, influenced in this point by the same fear which leads to rings for cannon being produced by the welding together of spirals, instead of making them in the common way for tiers by the punching and rolling of an ingot. In the same proportion, however, as greater experience and care lead to greater success being attained in producing more reliable ingots, the more complex method of piling and welding ought to be less frequently used. In any case, the series of experiments on plates above referred to as included in the exhibits of the Swedish Iron Board, are in my opinion so conclusive as to the superiority of the ingot plates over the puddled plates in the case of violent blows, that there can scarcely be any doubt but that soft ingot iron will, in course of time, completely replace puddled iron for armor-plates. The difficulty is to find the right degree of softness and to learn properly to handle the less easily-managed ingot iron. The largest armor-plate which the Paris Exhibition has to offer is of puddled iron, made by Marrel Frères, and has the following dimensions: — Length, 4.250 metres; breadth, 1.600 metre; thickness, 0.715 metre; and weight, 38,022 kilogs. As we have now seen not only how soft ingot steel, but in recent times even soft ingot iron, has begun more and more to take the place of wrought iron, it may not perhaps be out of place to point out in a few words how it has become possible to produce this soft ingot iron which has shown itself to be so superior. There are, indeed, some exceptional Bessemer works, as, for instance, Westanfors in Sweden, where, without any extra addition, the softest iron can be made without its suffering from any red-shortness, and this, as is well known, is more easy of accomplishment in proportion as the pig iron employed contains, on the one hand, more manganese, and, on the other, less sulphur. If a product free from red-

shortness is to be obtained, however, it is in general necessary, at the close, not only of the Bessemer, but also of the Siemens-Martin process, to add an iron more or less rich in manganese, and the quantity of manganese added must indeed be greater in the same proportion as the product is desired to be softer or poorer in carbon. This was the reason why Bessemer and Martin iron of proper softness could only be produced exceptionally until there was a supply of iron compounds very rich in manganese. For as compounds of iron and manganese commonly contain more than 4.5 per cent. of carbon, no great quantity of such a compound can be added, even to the iron poorest in carbon, without the content of carbon in the final product being so great that it ought not to be counted as iron, but as steel. As now, as has been stated, an addition of manganese, the amount of which must be ascertained in every separate case, in order that an ingot metal decarburetted to a certain degree shall be free of red-shortness, it follows that the richer in manganese the added substance is, the less of it requires to be used, and the less carbon accordingly is carried into the final product, or, in other words, it can be made the softer. This was already seen by several persons in the middle and towards the close of the decade 1860-70, and in particular, Mr. Kohn sought by articles in the newspaper *Engineering* to draw the attention of the makers of Bessemer and Siemens-Martin metal to the importance of using the iron compounds then considered rich in manganese, as containg 20 to 30 per cent., which were manufactured by Mr. Henderson at Glasgow in 1866 and 1867. This advice, however, was fruitless, and the manufacture of ferro-manganese soon came to an end from want of demand for the costly product. The matter, however, was soon taken up again by Terrenoire, which, thanks to its eminent engineer, Mr. Walton, understood better than other Bessemer works, the advantages which more manganiferous iron compounds were calculated to confer, and therefore purchased not only Henderson's but also Prieger's patent for the manufacture of ferro-manganese.

Since Terrenoire took the matter in hand the methods of producing this article have been rapidly improved, so that very soon ferro-manganese made in a Siemens furnace with from 50 to 60 per cent. manganese was offered for sale. The process of manufacture was still, however, costly, and the product, therefore, dear. The price, on the other hand, fell rapidly, when by the help of regenerative heating apparatus of the Siemens-Whitwell or Siemens-Cowper systems and very basic charges, success was attained in producing in coke furnaces ferro-manganese compounds, with over 80 per cent. manganese. Of the extension which the manufacture of ferro-manganese in the blast furnace has since undergone, the Exhibition gives a good idea, inasmuch as specimens, with more than 70 per cent. manganese, are shown by so many works that it is, perhaps, unnecessary here to enumerate them. The richest in manganese, with 87 per cent., is, however, made by les hauts fourneaux de Saint Louis, at Marseilles, now the seat of the most extensive manufacture of ferro-manganese. The furnaces under the management of Professor Jordan are, besides, the first which in France began to utilize on a great scale the rich and pure ores in which the coasts of the Mediterranean are so rich, and which have become of so great importance for the French iron manufacture. Besides spiegeleisen and ferro-manganese, there are manufactured here, all with coke, pig for steel for puddling, as well as Bessemer and Martin pig, along with a pig which is employed in competition with charcoal pig in Franche Comté forges, and finally, pig for malleable castings. The supply of ferro-manganese has led to a new method being employed for utilizing old worn-out rails, rich in phosphorus, begun at Terrenoire in 1874, and since very extensively followed. It has been long known that phosphorus has to a certain degree the same influence on the qualities of iron as carbon, inasmuch as both these substances diminish the ductility of the iron, but increase its hardness, modulus of elasticity, tensile strength, and disposition, when heated, to take the crystalline texture, with the resulting difficulty of working at very high temperatures, and brittleness in the cold state. The great difference between the influence of the substances, however, is that the action of carbon is much greater than

that of phosphorus in improving the qualities of iron by increasing its hardness, modulus of elasticity, and tensile strength, while on the other hand the influence of phosphorus far surpasses that of carbon in deteriorating its qualities by increasing the disposition to form crystals and by diminishing the ductility. Further, it had also been ascertained that the influence of phosphorus on the qualities of iron is increased in a very high degree by the simultaneous presence of a large content of carbon, so that the change in its qualities depending on a certain content of phosphorus is much greater in a steel rich in carbon than in an iron poor in carbon. These relations Terrenoire turned to account in the employment of its ferro-manganese. For by its help, it could, as has been already said, without danger of red-shortness, produce a final product so poor in carbon that the injurious influence of phosphorus upon it became much less than it otherwise would have been. Besides, it was possible, without to great an increase in the content of carbon, to obtain in the final product a considerable content of manganese, which had the double advantage that the manganese appeared at the same time to counteract the injurious influence of phosphorus on the iron, and in some degree to increase its hardness. The result of all this is, that while in so simple an object as rails, the quantity of phosphorus that could be permitted in an ingot steel with 0.5 to 0.6 per cent. carbon was scarcely 0.1 per cent., there may now with 0.2 to 0.3 per cent. carbon and 0.5 to 1.00 per cent. manganese be as much as 0.2 to 0.3 per cent. phosphorus. For rolling rails containing so much phosphorus there is required a more powerful rolling train than for purer carbon steel rails, partly because the more phosphoriferous ingot metal requires a greater extension, in consequence of which the ingots must be larger, and partly because ingot metal containing an excess of phosphorus cannot bear to be heated to so high a temperature as the less phosphoriferous. Nevertheless the product is, of course, inferior, both through increased brittleness and diminished hardness; but it appears as if it might be good enough for rails, at least in countries with a mild climate, and great are the advantages which the metallurgist has already been able to draw from this, not only in melting down and re-rolling old iron rails, but also through its being possible to use at Bessemer works a somewhat more phosphoriferous pig than before. In connection herewith I also beg to be allowed to point to the interesting series of experiments on the influence of carbon, phosphorus and manganese, on the physical qualities of iron, shown in the exhibits of Terrenoire. In general these experiments confirm what was before commonly accepted in this way, but there is one thing that forms an exception to this. The tension experiments made in Sweden appeared to show that the percentage of elongation at breaking is diminished with the content of phosphorus, while from the Terrenoire experiments, on the other hand, it appears as if a content of phosphorus of up to 0.3 per cent. had no special influence on the percentage of elongation at breaking. Should this observation come to be confirmed by continued experiments, it would afford the clearest proof of the insufficiency of tension tests alone as a means of judging of the goodness of iron, for the Terrenoire and the Swedish experiments agree in another point, inasmuch as they both show that phosphorus very considerably increases the sensitiveness of iron to blows. Even if tension tests of phosphoriferous iron give excellent results, increased tensile strength and undiminished percentage of elongation, it is nevertheless both in tests of a falling weight and of daily experience a settled matter that an exceedingly small content of phosphorus has an injurious influence on the power of resisting blows even of iron poor in carbon. It is not, therefore to be wondered at if the metallurgist devotes the greatest attention to the important question how phosphorus can be removed from iron. That this may be done to a high degree by suitable puddling at the same time that the quantity of phosphorus remaining in the puddled iron has not so injurious an influence on it as it has upon the more cinder-free refined iron of the Lancashire fire, and in a yet higher degree upon the quite cinder-free ingot iron, are facts which have been long known. This is, perhaps, easily explained by the lamellæ of cinder

counteracting the crystalline texture, with the resulting brittleness which phosphorus produces. Again, that puddling purifies from phosphorus so much more than the other refining processes depends, as is well known, on the circumstance that phosphorus must be removed from iron as a salt of phosphoric acid passing into the cinder, and neither the Bessemer nor Lancashire refining processes admit of this in a degree comparable with puddling. In order that the salt of phosphoric acid may be able to remain unchanged in the cinder, the latter must not be too acid or rich in silica, and its temperature must not be too high, for then the silica drives out the phosphoric acid, which, when set free, is immediately reduced by the carburetted iron with which it comes in contact, and enters into combination with the same. This is the case in the Bessemer process. Again, that Lancashire refining purifies iron from phosphorus in so much smaller a degree than puddling depends, without doubt, on the fact that charcoal in the open hearth is found in contact both with the iron and the cinder; and though the latter is commonly somewhat richer in protoxide of iron than in the case of puddling, and therefore ought to purify still more from phosphorus, this action is neutralized by the pieces of charcoal present, which reduce most of the phosphoric acid contained in the cinder that has passed into it, and thereby returns the phosphorus to the iron.

To how great a degree success has recently been obtained in freeing iron from phosphorus by adding rich iron ore or other materials rich in oxidized iron during puddling, appears very clearly from several French, Belgian, and English exhibits, which, though the ores employed are so phosphoriferous that their pig contains 1 to 1.5 per cent. phosphorus, yet show so beautiful cold worked specimens of their iron, that one not familiar with the facts would have difficulty in believing that the raw materials employed were so rich in phosphorus as in fact they were. All other exhibits of puddled iron are, however, in this respect far surpassed by that of Hopkins, Gilkes, and Co. of Middlesbrough, which show cold-worked samples of such excellence of iron, that one would far more readily believe that they were made from ores nearly free from phosphorus than from those of Cleveland, famous for the quantity of this substance which is found associated with them, and which yield a pig containing 1.5 per cent. This iron is made, as is well known, in rotating puddling furnaces; and it ought to be a pleasure for all who have taken part in the difficulties with which machine puddling has had to contend, to see that untiring perseverance appears at last to have gained its well-deserved reward. It would, however, ill become me to seek to enter further on the question of the superiority of the rotating puddling furnaces over fixed ones, as it is just this honored Association which has spread abroad nearly all the knowledge that is to be found regarding this subject. As, however, at the meetings of this Institute different furnace constructors have sometimes sought to hold out the greater effectiveness in purifying from phosphorus, as specially distinctive each of his own puddling furnace, I cannot omit to give expression to the view that it ought to be a point of superiority, common to all rotating puddling furnaces, that they purify from phosphorus more than fixed ones; for the more the phosphoriferous iron is exposed to the action of the fettling, rich in protoxide of iron, the more phosphorus ought to be removed; and it would be perhaps difficult to bring about in a fixed furnace a contact between these materials so often repeated as is attained by the rotating puddling furnace without manual labor. Iron made in the rotating puddling furnace is also exhibited both by Creusot and by the Compagnie des Forges de Donain et d'Anzin. The latter works has a Crampton's furnace, while Creusot has for more than two years had at work two modified Danks furnaces, with a double plate covering, through which water circulates. Such a furnace is to be seen in the magnificent pavilion of Creusot. The iron made with it is stated to be nearly free from phosphorus, but it is also manufactured from a pig very poor in phosphorus. It is clear from the foregoing that one way of producing ingot metal, even from very phosphoriferous pig, would be first to puddle it in a rotating furnace, and then to fuse the puddled iron thus obtained with pig poor in phosphorus. But, on

the one hand, such puddled iron, notwithstanding the beautiful cold-worked specimens exhibited, is not in general so poor in phosphorus as is desirable for ingot metal of first-rate quality, for Hopkins, Gilkes, and Co.'s iron, according to the analyses given, contains from 0.08 to 0.17 per cent. phosphorus; and, on the other hand, such iron, up to this time at least, has not been made so cheaply that it could be expected to compete in the way that has just been pointed out with Bessemer metal, now so low in price.

The great importance which the question of how ingot metal is to be produced from very phosphoriferous raw materials has, for such a district as that of Cleveland, gave occasion, as is well known, to the very thorough and interesting researches of Mr. I. Lowthian Bell. With the same frankness and love for scientific enlightenment which induced him formerly to lay before this Institute his comprehensive researches regarding the blast furnace, which placed it in an altogether new light, he has also, in several memoirs which have been read with the greatest interest over the whole world, given an account of his attempts to purify pig iron from phosphorus. By these experiments Mr. Bell has, in the most indubitable way, not only confirmed and thrown still further light on what science had formerly more or less thoroughly ascertained in this department, but he has, moreover, succeeded in devising a method of applying on a great scale the scientific results at which he has arrived. He has also communicated so much on this point to this Institute that it would be unnecessary, not to say improper, for me to discuss this subject further, were it not the aim of this paper to endeavor to point out the most interesting objects which are to be found in the Paris Exhibition relating to the manufacture of iron and steel; and what iron metallurgist can well deny that Mr. Bell's exhibit has an interest with which scarcely any other than that of Terrenoire can come into comparison. I ought, therefore, perhaps to be forgiven if, notwithstanding all that Mr. Bell himself has already communicated to this Association regarding his plan of purifying from phosphorus, I, too, beg to say a few words on this subject. For a long time back there has been employed in some districts, as is well known, a preparatory refining process in a separate hearth or furnace, after which the pig which had undergone this process was finally refined to malleable iron in another hearth or furnace. The object of this preparatory refining was partly to diminish the content of silicon in the pig iron, and thereby render it more suitable for the final refining process, and partly to diminish the percentage of phosphorus in the pig iron, and thus obtain a less phosphoriferous final product. Both these objects Mr. Bell has had in view with this process, but he has succeeded far better in attaining them than had been done previously, the reasons of which we shall soon see. In the common running-out fires the pig iron is melted in contact with the fuel, and even if substances rich in oxidized iron are added to it, it is certain that the purification from phosphorus can never in this way be complete; but when we consider the fact already stated, that the Lancashire hearth refining purifies from phosphorus to a very inconsiderable degree, we rather find occasion for surprise that the common running-out process can take away so much phosphorus as it does. The reason, however, lies in the following two differences between hearth-refining and the running-out process:—(1) In the former the phosphorns, which has been taken up by the cinder as a salt of phosphoric acid, comes into simultaneous contact with carbon and more or less decarburetted iron, and it is a fact, which is proved by several circumstances, that iron combines both with phosphorus and several other metalloids with greater attractive force in proportion as it is purer and more refined. In the running-out fire, on the contrary, the pig iron is never decarburetted in any noteworthy degree, and it therefore never acquires so strong a disposition to reduce the phosphorus out of the cinder and again enter into combination with it. In the running-out fire, too, the fused iron in general does not come into simultaneous contact with the cinder and carbon, but a cinder bath is interposed between the fused iron and the carbon, while, on the contrary, the iron during the operations in the refining hearth comes into such simultaneous contact with the cinder and carbon as has as its result the reducing of the

phosphorus and its re-combination with the iron. (2) In the refining hearth the iron is subject during the latter part of the process to a higher temperature than is the case in the running-out fire.

The running-out fire process has exceptionally been carried on in a reverberatory furnace without contact with the fuel, and as the purification from phosphorus which takes place in the puddling furnace is so much more complete than that which is accomplished in the Lancashire refining hearth, we might well have supposed that a reverberatory furnace would be distinguished in the same way in comparison with a common running-out fire. As reverberatory furnaces have been arranged, this, however, has scarcely been the case; and the reason of this is not difficult to find, when we consider that such furnaces have been lined with sand or masses of quartz, which prevent the cinder from being sufficiently basic or rich in oxidized iron; and we ought never to forget the fact already touched upon, that, if any considerable purification from phosphorus is to be brought about, the cinder must always be kept so basic that the silica is well saturated, and so has not too strong a disposition to liberate from the cinder the phosphoric acid, which is then reduced, and enters into combination with the iron as phosphorus. All these defects, inseparable from the old method of refining, Mr. Bell has now succeeded in avoiding by running pig iron rich in phosphorus into a reverberatory furnace, lined with iron ore, or some other substance, rich in oxidized iron, and then, at a temperature not exceeding that which is required to keep the pig fluid, by bringing about, either by the nature of the furnace itself or by stirring, a powerful action of the peroxide of iron on the pig. The result of this has been striking; a ton of molten pig iron, with 1.8 per cent. silicon, 1.4 per cent. phosphorus and 3.5 per cent. carbon, being changed in ten minutes into a product with only 0.05 to 0.1 per cent. phosphorus and 3.3 per cent. carbon. The waste is only about 2.5 per cent. Several different kinds of reverberatory furnaces have been tried for this purpose, but that which for the present is believed to be the most suitable is Pernot's flat furnace on an inclined axle. The refined pig is run out into cakes, which it is then the intention to melt down, along with some rich iron ore poor in phosphorus, in a Siemens regenerative furnace without crucibles, to ingot metal according to the Landore method. Mr. Bell, however, has not for the present any such furnace at his disposal; and the specimens of ingot metal included in his exhibit, accordingly, have not been produced by himself, but have been prepared according to his method from Cleveland pig at Woolwich, where the smelting has proceeded in a furnace of Mr. Price's well-known construction. This has its peculiar interest, as the circumstance that soft steel and iron may be kept fused in Price's furnace further confirms the fact already proved by the low consumption of fuel, that this furnace is in a high degree regenerative. As Mr. Bell's process has only been employed experimentally, it is of course yet too early to give an opinion on its future. The first question with reference to it is, whether it can be got to work so uniformly that the purification from phosphorus will be always equally complete, and the product accordingly quite reliable. This ought best to be attained by the help of a self-acting furnace. The second question is whether this method can be made cheap enough, so that the ingots thereby produced will be able to compete in working expenses with Bessemer ingots. A main factor in judging of these questions is the endurance of the lining of the refining furnace. If it can be got to stand pretty well, the process itself goes on so fast that the refined product must be quite cheap. As, besides, it consists almost exclusively of iron and carbon, its decarburretting with rich ore ought to proceed in a considerably shorter time than is commonly required for the open hearth process, and there thus appears to be a good prospect of producing from a pig, rich in phosphorus, an ingot metal both cheaper and poorer in phosphorus than is possible by machine puddling. The final determining factor will, of course, be the difference in Bessemer pig produced from ores poor in phosphorus, and the Cleveland rich in phosphorus, and Mr. Bell's process ought, therefore, at least, to become a regulator of the excess in price of the sorts of pig which are poor over those which are rich in phosphorus.

As the drawn out ingot metal has recently more and more replaced the wrought iron, steel castings have also more and more encroached upon the territory of iron castings, inasmuch as a great many things, in which more than ordinary strength is required, are now cast in steel instead of iron. For this purpose crucible steel has been used for a long time back, but it has since become more common to employ, not only Siemens-Martin, but also Bessemer steel. The Exhibition is so rich in Siemens-Martin castings, that it would not repay the trouble to enumerate the different exhibitors, but Angleur, in Belgium, ought, perhaps, to be mentioned as exhibiting Bessemer castings of more than common merit. In order that the castings may be considered of first-rate quality, it is, of course, requisite that they be compact, and the greatest difficulty in their production is, as is well-known, just the fulfilment of this main condition. As the blow-holes in steel are caused by the escape of gases which have not reached the upper surface of the casting previous to its cooling, and as, further, this escape of gas arises partly from the gases which the steel has taken up during its formation or melting, and partly from the carbonic oxide which is formed by the action of the oxygen distributed through the steel, or, perhaps, more correctly of oxide of iron upon the carbon of the steel, it is easy to understand that the difficulty of getting steel castings compact is least with crucible melting, greater with the Siemens-Martin, and greatest with the Bessemer process. So long as the castings are made of hard steel, the difficulties in this respect are, however, comparatively easy to get over, but in steel castings a greater ductility is often required than that which hard steel possesses, and it is, therefore, necessary in many cases that the steel be soft, with only 0.5 to 0.6 per cent. of carbon. A very common way of attaining this end is to cast pieces of very hard steel, and afterwards, in the same way as is common in the production of malleable castings, to subject them to heating in a powder of oxides of iron, which diminishes the content of carbon in the steel castings from without inwards. Compact steel castings, with the ductility increased in this way, are also exhibited from several works, as, for instance, by Dalifol in Paris and G. Fischer at Schaffhausen. A method that has been long employed to promote freedom from blow-holes in steel castings is to add a pig iron rich in silicon to the soft steel while it is being melted, for the thus increased content of silicon in the steel counteracts, as is well known, both the taking up of gas during melting and the formation of carbonic oxide during the cooling of the cast steel. The common content of silicon in the products of various works famous for their compact steel castings has, therefore, been about 0.30 per cent. Thanks to its more than ordinary skillful engineers, M. Walton and his successor M. Pourcel, and a management with correct application for the requirements of the times, Terrenoire has now further developed this manufacture by adding at the close of the melting of the steel so-called "fer-manganese-silicium," or a pig iron rich in manganese and silicon. The richest specimen of this which the Exhibition has to show contains 20.5 per cent. of manganese and 10.5 per cent. of silicon. The advantage of this is, that when the oxygen dissolved in the steel or the oxide of iron comes into simultaneous contact with manganese and silicon, both these substances are oxidized, and there is formed a double silicate of protoxide of iron and manganese, more fusible and fluid than the silicate of protoxide of iron, which is formed when only a pig iron is added which is rich in silicon but poor in or free of manganese. Through the greater fusibility and fluidity of the silicate thus formed, there is naturally a diminution of the danger that it will not completely rise to the upper surface of the steel and there separate itself as a layer of slag, but remain in the interior of the casting as a network, and thus diminish its strength. It is clear, however, that it is not necessary for this purpose to use "fer-manganese-silicium," which must be very difficult to manufacture, inasmuch as the obtaining of the greatest possible quantity of manganese in a pig iron demands conditions on the blast furnace burden quite opposite to what is necessary for attaining the greatest content of silicon; for the former requires the minerals not only to be very rich in manganese, but also to be as basic

as possible, while for the production of silicious iron it ought to be as acid as possible. The end in view, viz., the simultaneous addition of manganese and silicon to the steel, ought as easily to be attained by the addition of a fused mixture of ferro-manganese and a very silicious pig, and in such a case the difference is small from the method formerly employed of using ferro-manganese instead of spiegeleisen. The advantage of the Terrenoire process is thus that by means of it we can directly manufacture a softer, and in consequence a more ductile, but still compact product than was previously possible. There are also now produced at Terrenoire only steel castings poor in carbon, for the hardest, or those that are used for armor-piercing projectiles, contain, according to an obliging communication by M. Pourcel, not more than 0.5 to 0.6 per cent. of this metalloid.

It would appear from several publications in technical periodicals descriptive of the Terrenoire process, as if silicon has been found not only to promote the compactness of steel, but also otherwise to improve its qualities. This is, however, by no means the case; but experience at Terrenoire has completely confirmed the old opinion, that the greater the content of silicon in a steel, otherwise of similar quality, the more sensitive it is to blows. The addition of silicon is considered simply as an evil necessary for the sake of the compactness of the steel wares, and great importance is placed on not adding a superfluous quantity of silicon, in order that the content of it in the product may not be greater than is absolutely necessary.

For ingot iron and steel, which are subjected to shingling or rolling, and whose blow-holes, therefore, may be rendered harmless by welding, M. Pourcel will, on no account, employ any addition of silicon. The most common content of silicon in their steel castings is stated to lie between 0.2 and 0.3 per cent., and such a content of silicon is considered pretty harmless. The very considerable percentage of manganese—0.55 to 0.7—which their steel contains doubtless contributes to this, for metallurgists had previously believed that they found that manganese counteracted the injurious influence of silicon on the qualities of iron.

At Terrenoire there has been a higher aim set up by degrees in the production of steel castings, and their very fine exhibit shows that they now even reckon on being able to substitute castings for a number of articles for which malleable iron or steel is used for the present. For besides armor-piercing projectiles, both massive and hollow, and cylinders and other parts of hydraulic presses, there are to be found exhibited not only tubes but also rings for cannon, cranked axles, and other similar unhammered castings. Although all these articles are unhammered, both the surfaces of fracture exhibited and the tension and other tests, the results of which are communicated, show that the physical qualities of the finished products correspond pretty closely with those which distinguish hammered ingot metal with the same chemical composition. On this point, as is well known, various communications have not only been made to this Institute, but others have appeared in various journals, and I, for my part, confess that nothing exerted on me a force so attractive to the Paris Exhibition as just the hope of being able there to find an explanation of the problem, hitherto unexplained so far as I am concerned, by the published communications to which I have referred, viz, How the qualities of ingot steel may be so changed without hammering that they become comparable with those of hammered steel. Nor has this hope been disappointed, for from the Terrenoire exhibit, and the printed description of it, it is clearly evident that this alteration in the qualities of steel is brought about by hardening. A rapid cooling of a large piece of steel heated to a red heat acts upon it in quite the same way as a hammering, for the contraction of the outer layer caused by cooling must bring about a powerful compression of the interior layers. In order, however, that this action be sufficient, it is necessary that the modulus of elasticity of the material be so high that the resistance of the inner layers to the action of the outer do not produce in the latter a set, or permanent extension, whereby the compressing action is diminished. The iron intended for the purpose ought, therefore, not to be too

pure, for the modulus of elasticity of pure iron is, as is well known, very low. But, on the other hand, the content of carbon in the material ought neither to be too great nor the steel too hard, for otherwise it is difficult to modify the hardening that its action be not too powerful when the ductility becomes lessened and the product brittle. In this way it is explained why it appears most advantageous to keep the percentage of carbon between 0.3 and 0.6, the lesser quantity for larger and a greater for smaller pieces, and in general to carry out the hardening in oil. Should the material be rather hard for the intended purpose, the more moderate hardening which is produced by the cooling of the piece in air may be best, or the excessive hardening must be succeeded by a tempering whereby the ductility of the material is increased.

If these explanations of the facts shown by the Terrenoire exhibit be correct, it follows that if the best results are to be obtained, not only the hardening but also the preparation of the steel must be managed with the very greatest care and attention. The melting is carried on at Terrenoire in Siemens furnaces, without crucibles, and Mr. Holley has, in the *Metallurgical Review*, given an interesting description of the way in which the changes of the steel bath succeed each other, and, partly by the help of the appearance of the slag, partly by hammering samples taken out of the bath, the proper moment is determined for adding the compound of iron, manganese, and silicon. For castings, compactness is naturally of greater importance than for ingots, which are afterwards to be drawn out; but even for the latter compactness is far from being a matter of indifference if it can be attained without the sacrifice of any other good quality, for unfortunately the ingot blow-holes are far from being always properly welded together when the ingots are drawn out. It is therefore not to be wondered at, that experiments have been made at many places to prevent the formation of blow-holes by means of powerful hydraulic pressure applied during the cooling and solidification of the cast steel or iron. This plan has been tried at several places, as, among others, at St. Etienne by V. Biétrix et Cie., but it has never been regularly employed except by Sir Joseph Whitworth and Co., Manchester, where, as is well known, this method has been in use for more than ten years. Exceedingly beautiful articles are exhibited by this firm, world-famous for its accurate workmanship, among which may specially be mentioned a hollow cylinder with an interior diameter of 1.98 metre, and a length of 1.5 metre, and a thickness of material of only 4 centimetres, a torpedo guaranteed to resist an interior pressure of air of 105 kilogs. per square centimetre, and a hollow axle 10.26 metres long with an exterior diameter of 45, and an interior of 30 centimetres. All these pieces are made from hollow ingots, which, when under preparation, are exposed to powerful hydraulic pressure, after which the ingot that has been thus treated is further worked by means of a hydraulic compression; but, unfortunately, it is impossible to obtain at the Exhibition any more detailed account of this interesting method of working.

Finally, with regard to crucible-melted tool steel, the Exhibition has nothing properly new to offer under this head, if we do not consider chrome steel as such. This, as is well known, is made by adding a pig iron rich in chrome, and such a pig, along with tungsten pig, is found, among others, in the exhibit of Terrenoire. The iron compound richest in chrome, containing up to 65 per cent., is however exhibited by J. Holtzer, Dorian, et Cie.'s steel works at Unieux, near St. Etienne, and it is made by the reduction of chrome ore with charcoal in the crucible. The last-named exhibit also contains the largest quantity of chrome steel. The tension tests to which this steel and the chrome steel from Terrenoire have been submitted have further confirmed the statement previously made in other quarters, that chrome still more than carbon increases, not only the hardness, but also the modulus of elasticity and the tensile strength, while at the same time it does not diminish the ductility so much as carbon. The action of chrome is thus exceedingly advantageous, and much resembles, but is believed to be still more powerful than that of tungsten. Jacob Holtzer's steel, which is richest in chrome, is said to contain 2.5 per cent. The beautiful exhibit of Seebohm and Dickstahl, of Sheffield, also

contains chrome steel, with only 1 per cent. chrome. Wolfram or tungsten steel is shown, not only by the exhibitors of steel just named, but also by several others, among which may be specially mentioned the very beautiful exhibits of crucible steel of, first and foremost, the Innerberger Hauptgewerkschaft, but also of Eibiswald in Styria.

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers.—The last issue of the "Transactions" contains the following paper and discussions:

No. 162. The South Pass Jetties: Descriptive and incidental notes and memoranda, by E. L. Corthell.

Discussions on the South Pass Jetties, by C. W. Howell. E. L. Corthell, C. Shaler Smith and J. Foster Flagg.

Addition to Paper No. 160, by James B. Francis.

This number also contains plates, from No. XIV to XX inclusive, illustrating South Pass Jetties, and Plate XXI showing the Mouth of the Magdelena River.

Engineers' Club of Philadelphia.—At the last meeting of the Club, Professor Lewis M. Haupt, President, read a memorial to the State Legislature, praying that an appropriation be made to co-operate with the General Government in the more vigorous prosecution of the Geodetic and Topographical Survey of the State, for the following reasons:

1st. The imperative demand for such work to supply correct maps for the true representation of the geology of the State.

2d. Correct maps are necessary to the proper development of the State.

3d. To reform the system of land surveying now the source of so many uncertainties in consequence of the secular changes in variation of the magnetic meridian; and,

4th. The ultimate economy of accurate surveys.

The memorial closed with a statement of the organization required for such works.

In supporting it, Mr. Ingham, Commissioner for the Second Geological Survey, said that they have found the present maps, boundaries, &c., to be utterly worthless as regards accurate location. In many cases requiring the geology to be forced to fit county lines, and regretted that this State had not already taken steps to remedy this evil. After further discussion action was postponed.

Mr. A. A. Roberts laid before the club the original drawings for structures on the Allegheny Portage Road (1831–6); among others the plan of the first tunnel in America. These he has recently discovered.

A letter from Mr. J. Christie, corresponding member, was read in relation to simplifying formulæ for strains in rolled iron I, T and L beams, giving result of some experiments recently made.

Mr. Henry G. Morris exhibited plans of several boilers, which he had used with good results, and showed comparative merits of each; also plans of sugar-making machinery, with detailed explanations.

Mr. Mucklé presented drawing of Eave's new safety valve, from "Atlas Steel and Iron Works," and showed its advantages. Also read a description of Haddan's Military or Pioneer Railway, recently placed before the Royal Institution, and, when on trial, a section was erected at a speed equivalent to a mile a day for every hundred men employed. This was over uneven ground.

Louis C. Madeira, Jr,
Secretary pro tem.

Premiums from the Institution of Civil Engineers.—The originality, labor, and ingenuity displayed by the authors of some of the communications submitted to the Society during the session 1877–78 have led the Council to make the following awards:—

For Papers read at the Ordinary Meetings.

1. Telford Medals, and Telford Premiums, to R. W. H. Paget Higgs, LL.D., and J. R. Brittle, for paper on "Some Recent Improvements in Dynamo-Electric Apparatus."
2. A Watt Medal, and a Telford Premium, to H. Davey, for paper on "Direct-acting or Non-rotative Pumping Engines and Pumps."
3. A Telford Medal, and a Telford Premium, to T. Curtis Clarke, for paper on "The Design generally of Iron Bridges of very large Span for Railway Traffic."
4. A Watt Medal, and a Telford Premium, to Bradford Leslie, for paper on "The Hooghly Floating Bridge."
5. A Telford Premium to J. Atkinson Longridge, for paper on "The Evaporative Power of Locomotive Boilers."
6. A Watt Medal, and a Telford Premium, to Alfred Holt, for "Review of the Progress of Steam Shipping during the last Quarter of a Century."
7. The Manby Premium to E. Bazalgette, for paper on "The Victoria, Albert, and Chelsea Embankments of the River Thames."

Other medals were awarded for papers printed in the proceedings without being discussed, and for papers read at the supplemental meetings of students.

IRON AND STEEL NOTES.

Steel at the Paris Exhibition.—The numerous visitors to the Machinery Hall must have observed an exceedingly choice assortment of Messrs. H. Augustus Guy and Company's Specialties, foremost among which figures their well-known invincible tool steel in the ingot, bar and representative tools. We understand that these gentlemen, in the exercise of their undoubted rights declined to admit the jurors into the secrets involved in the materials and manufacture of their monopolies. Consequently their exhibits were not adjudged for awards. Of course, when a firm has devoted years to a valuable improvement, in a commodity like tool steel, and is beginning to

feel the advantages of success, it certainly requires much more than average self-abnegation to disclose the details of their system to the world. They, however, proposed a very ample equivalent, so far as the jurors were concerned, and the public more especially, in their offer to submit sample bars of any size or section for the most crucial tests, in competition with all manufacturers, to make good their claims to the highest honors, and it is to be regretted that this course, which is, after all, the only true criterion, was not adopted. We had an opportunity this week of inspecting at the firm's London office some new specimens, which, we were informed, embody the discovery and successful application of further improvements. Guy's "True" boiler cleaner for removing and preventing incrustations in land and marine boilers was also exhibited, and aroused considerable interest. It has a double value, and meets a very serious difficulty—a problem which a protracted inquiry on the part of our own Government has failed to solve satisfactorily—for it prevents oxidization of the boiler plates, while it also moderates priming, and in this capacity must be of great value.

THE USE OF STEEL FOR STRUCTURAL PURPOSES.—The final report of the committee of the British Association on the use of steel for structural purposes states:—"Having given the subject our best consideration, we recommend that the employment of steel in engineering structures should be authorized by the Board of Trade under the following conditions, namely: (1) That the steel employed should be cast steel or steel made by some process of fusion, subsequently rolled or hammered, and that it should be of a quality possessing considerable toughness and ductility, and that a certificate to the effect that the steel is of this description and quality, should be forwarded to the Board of Trade by the engineer responsible for the structure. (2) That the greatest load which can be brought upon the bridge or structure, added to the weight of the superstructure, should not produce a greater strain in any part than 6½ tons per square inch. In conclusion, we have to remark that in recommending a co-efficient of 6½ tons per square inch for the employment of steel in railway structures generally, we are aware that cases may and probably will arise when it will be proposed to use steel of special make and still greater tenacity, and when a higher co-efficient might be permissible, but we think these cases must be left for consideration when they arise, and that a higher co-efficient may be then allowed in those instances where the reasons given appear to the Board of Trade to justify it." This report has since been acted upon by the Board of Trade in the printed paper issued by them in reference to railway structures. "It will be observed that a co-efficient of 6½ tons per square inch is assigned to steel, that of iron being 5 tons per square inch. This increase of the co-efficient will effect important economy in structures, especially in bridges of large spans, and will also tend generally to increase the employment of steel for railway and shipbuilding purposes. The labors of your committee having ended in such a satisfactory manner there is no necessity to re-appoint them." The report is signed by Mr. E. H. Carbutt, Mayor of Leeds, as Secretary.

THE MECHANICAL AND OTHER PROPERTIES OF IRON AND MILD STEEL.—Numerous experiments have been conducted by several eminent engineers to prove the tensile strength of iron and steel, both in the shape of bars and plates. Unfortunately, however, many of the tests have been carried out with rude testing machines, rendering it difficult to obtain a true result of the endurance and strength of the metal under investigation. Some experiments were conducted with a view to determine the strength of steels with fixed proportions of carbon only, by Mr. Vickers, of Sheffield, and recorded by him in a paper read on the subject before the Mechanical Engineers of England, August 1st, 1861; but as these tests were more especially resorted to to ascertain the strength of crucible steels, mostly used for tool-cutting purposes, they were of but little value to the constructive or mechanical engineer. Mr. Adamson, having used practically a comparatively mild class of steels or ingot irons for the last twenty-one years, at times found, from cold mechanical bending tests, some irregularities in the working of the metals. This indicated to him the necessity of more careful investigation, both as to their composition and the temperature at which they could be manipulated in the workshop and practically applied; and in the present paper his object was to put before the members a record of the endurance of iron and steel when subject to concussive force such as can be produced by gun-cotton, gunpowder, or other explosive materials. The experiments carried out were instituted with a view to ascertain what would be the effect on a steam-boiler working under pressure by the side of an exploding boiler, or the effect on a ship by a collision with another, and whether wrought iron or steel possessed the greater power to resist such accidentally produced force. Uniformly the various trials made by the writer in June, 1876, were favorable to mild steel. Drift and tensile tests pointed emphatically in the same direction. The value of steel and iron for structural purposes was also tested, and contrasted with that of iron, the result being to show that steel with about one-half per cent. of carbon, 1 per cent. of manganese, with a low measure of silicon, sulphur and phosphorus, can be depended upon to carry double the load of the best wrought-iron plates that can be produced, and with as good results as regards elongation. After many trials and many failures in attempting to weld steel boiler plates, the writer found it necessary to ascertain in all cases the composition of the metal before putting any labor upon it. From a large experience it is now found desirable that the carbon should not exceed one-eighth per cent., while the sulphur and phosphorus should, if possible, be kept as low as .04 silicon being admissible to the extent of one-tenth per cent. The writer then passed on to describe a variety of tests of the malleability of iron and steel, their powers of endurance under color-

heat, &c., and followed with the observation that from the experiments he had explained, it would be apparent that the users of metals must make some natural selection, as it were, to secure the highest and best results for any special purpose. It would also be clear that no wrought iron could resist concussive force equal to mild steel, and as a much higher range of ductility and carrying power was attained, he had no doubt constructive engineers would feel themselves constrained to use it much more extensively in all cases where strength and lightness were required. Should it ultimately be proved that sea-water would destroy steel quicker than wrought iron, the use of wrought iron for the skins of ships might be continued; but, with present knowledge, nothing, in his opinion, existed to prevent the whole framework of every steamer and sailing vessel being constructed of Bessemer or Martin-Siemens steel, as at least one-third the weight might be saved at the same time that greater security was ensured. In the diluted sulphuric-acid bath the evidences were quite clear in favor of mild steel and the purest iron to resist corrosion, but before as much could be said as to the influence of sea or salt water a more extended and careful series of experiments would be required. The same might be said of the selection of metals for the construction of artillery; and the writer had no doubt that, by a still more careful manufacture, to keep down the carbon and injurious alloying substances common to wrought iron, most enduring armor plates might be manufactured by the Pneumatic or Martin-Siemens process. Further, there could be no doubt that the medium hard class of steels, possessing double the strength of the best wrought iron that can be made, ought, without exception, to be used for building bridges and numerous other like structures.

RAILWAY NOTES.

A NARROW-GAUGE railroad has been proposed in Guatemala, and agents are now in San Francisco for the purpose of interesting capitalists in the scheme. It is understood that a section of thirty miles, to penetrate the coffee region, will be first made, and, if successful, the road will be extended to the capital of the State. Should the necessary capital be secured in San Francisco, it is claimed that the trade of Guatemala will be attracted to that city. If the necessary aid cannot be secured there, an appeal will be made to the capitalists of the East or of Europe.

OF all the sources of railway disasters, shunting operations are perhaps the most prolific; but this truth has either failed of appreciation by railway directors, or satisfactory means of removing the danger have not appeared. Among other inventors who have attempted this, however, Mr. Barrow, of Rock Ferry, Liverpool, has recently finished an apparatus for the protection of sidings during shunting operations. The signal consists of a revolving signal and lamp fixed in the six-footway, 2 ft. high, some 500 and 800 yards from the point, and worked by the points-man in the signal-box. The lever or wheel which works the light also manipulates a couple of fog signals. When the light is turned against a coming train the fog signals are placed on the line by mechanical means, so that should the driver miss seeing the light, the fog signals warn him in time to avert disaster.

GREAT activity is just now being shown in the Austro-Hungarian Empire in the prosecution of all kinds of public works, and especially of those in any way relating to the extension of the railway system of the country. Amongst others, there is a talk of the construction of an iron bridge over the Drave at Eszeg, to replace the present ferry, at a cost of 800,000 fls., which would be carried out partly by the Government and partly by the Alfoeld and Fiume Railway Company, which is domiciled at Pesth. It is also proposed to replace by iron bridges all the wooden bridges on the line worked by the Alfoeld and Fiume Railway Company, and the Kaschau and Oderberg Railway Company, &c., and the construction of the proposed lines of railway on the military borders of Croatia and Slavonia is to be offered for public auction—in fact, according to *Herapath*, one line has already been adjudged.

THE supplement to the last *Gazette of India* contains some interesting statistics of the number of servants of all races employed on the different railway lines in India. The grand total for 7,278 miles of line is 132,040, or between eight and nine individuals per mile. Of these 132,040 persons, 125,040 are natives, 3,319 are Eurasians—children of Europeans but born in Asia—and 3,607 are Europeans. Again, of the total number 8,837, of whom 8,257 are natives, 271 Eurasians, and 309 Europeans are employed in the department of general administration; 31,616, of whom 29 339 are natives, 1,233 Eurasians, and 1,044 Europeans in the traffic and telegraph departments; 52,259, of whom 51,631 are natives, 248 Eurasians, and 380 Europeans in the engineer's department; and 39,328, of whom 35,787 are natives, 1,567 Eurasians, and 1,874 Europeans, in the locomotive and carriage departments. The first thing that strikes us about these figures is the enormously large proportion of natives, not only in the total, but in every individual branch of the work. In fact, it may almost be said that the working of the railways is practically in the hands of the natives of the country—in some cases, but not in all, under European supervision. The insignificant number of Eurasians employed is hardly less striking. In one department alone—traffic and telegraph—does it exceed that of the Europeans. Turning again to the statistics of casualties, we find that among an average number of 3,513 Europeans employed in the year ending 30th September, 1877, there were only eighty-three deaths, while among an average number of 3,319 Eurasians employed there were only thirty-nine deaths, giving about half as high a death rate for Eurasians as for Europeans. The dismissals were 289 and 256 respectively, showing no great disparity between the two classes.

RAILWAY ACCIDENTS.—The *Annales des Ponts-et-Chaussées* has just published some interesting statistics on the above named subject. In the old days of diligences, or stage-coaches, one passenger was killed out of about 335,000, and one wounded out of 30,000; while out of 1,784,404,687 persons carried by the French railways from September 7th, 1835, to December 31st, 1875, only one was killed out of 5,178,490, and one injured out of 580,450. If the accidents are divided into two groups, from September, 1835, to December, 1855, and from January, 1856, to December, 1875, we find that in the first period one traveler was killed out of 1,955,555, and one injured in 496,555. In the second, the proportions were one killed out of 6,171,117 passengers, and one injured in 590,185. As is seen, the number had considerably decreased in the second period. Of late years, the proportion has still further diminished, and the results for such countries as France, England, and Belgium are particularly striking. In France, during the years 1872, 1873, 1874, and 1875, one passenger was killed out of 45,258,270, and one hurt in 1,024,360. In England, from 1872, to 1875, one was killed out of 12,000,000 persons carried, and one wounded in 366,000. In Belgium, from 1872, to 1876, one was killed out of 20,000,000 passengers, and one injured in 3,500,000. To sum up, a person had, in France, in the time of the diligences, a chance of being killed in making 300,000 journeys, and of being hurt once in making 30,000. On the railways, from 1872 to 1875, the chances were reduced to one death in 45,000,000 journeys, and one injury in 1,000,000. Thus, a person continually traveling by rail, at a speed of 50 kilometers ($\frac{5}{8}$ of a mile each) an hour, would have had, during the three periods above indicated, the following chances of being killed: From 1835, to 1855, once in 321 years; from 1855 to 1875, once in 1,014 years; and from 1872 to 1875, once in 7,450 years.

QUEENSLAND RAILWAYS.—The Queensland Minister of Works has intimated that the Queensland Government has no intention of undertaking the construction of proposed branch lines from Ipswich to Fassifern, in one direction, and to Mount Esk in the other, unless the residents in the districts to be benefited by their construction contribute towards the cost, which, we suppose, means that a system of rating railway districts is in contemplation. The proposed branch line from Oxley to Beenleigh, is one with regard to which considerable pressure is likely to be brought to bear upon the Government; but a contention has arisen in favor of a diversion of the route so as to serve the settlers of the Upper Logan and the Albert. The Colonial Sugar Refining Company of Sydney are forming an establishment on the Tweed river, immediately south of the Queensland Border, for the production of sugar on an extensive scale. They have purchased 10,000 acres of land, intending in the first instance to grow their own cane, in the expectation, however, that as soon as machinery has been erected for crushing and refining purposes, farmers will settle in the neighborhood, and enable the company to adopt the plan which they have found eminently successful on the Clarence river, where they last year exported about 7,000 tons of sugar, none of which was from cane of their own growing. But the Tweed is difficult of navigation, and the company have asked the Queensland Government to construct a short line of railway or tramway from the Border to Nerang Creek, Queensland, with the view of making that the port for the produce of the Tweed district. The company further ask whether, in the event of the government declining to undertake the work, they will permit the company to make the line, and, if so, upon what terms. The length of line will not exceed 15 miles.

ENGINEERING STRUCTURES.

THE work of tunneling the St. Gothard Railway is being pushed on with considerable rapidity. A telegram from Geneva states that on the Goeschenen side alone 1,000 men are employed inside the tunnel and 400 outside. Three hundred wagon loads of earth are excavated every day, and in the daily blastings 600 lbs. of dynamite are used. Equal energy is being shown on the Italian side.

THE ALTENBURG TUNNEL.—H. Von Oer gives a full and detailed account of the system of supports adopted at the Altenburg tunnel, where iron was made use of in place of the usual timbering. The system, as there carried out, is due to Herr F. Rziha, an Austrian engineer, and is a modification of that in use in the Saxon mines for the timbering of drifts. The author claims that it possesses all the advantages of the English system, as designed by Brunel, without its defects. It consists essentially in the adoption of the arched form, embracing the whole section of the tunnel, the structure being built up of short segments, varying in length from 1 metre to $1\frac{1}{2}$ metre (3.28 to 4.9 feet), composed of angle iron, and joined together by the flanges. A characteristic feature of the system lies in the application of the common forms of angle iron, by which means economy in the cost of the materials is secured. Herr Rziha makes large use indeed of old rails; and the paper gives a drawing showing the arrangement of these materials. The construction is a kind of double arch, the outer ring of which supports the earth, and itself rests upon the inner ring, which is designed to serve as the centering upon which the masonry is to be built in. As the work of excavation advances, the outer ring supporting the rock is removed in small portions at a time, and the bricking is built up upon the lower ring. The distance between the two rings being made to correspond to the required thickness of the arch. The several parts of the structure are simple in form, light, and easily put together. The erection is carried on, as the excavation progresses, in a manner similar to that followed in the ordinary method of timbering. The system is said to be a very efficient one, and a tabular statement of quantities and cost shows it to be also remarkably cheap. In one case, the econ-

omy resulting from the adoption of iron instead of wood, amounted to as much as 84 marks per lineal yard, the estimates being 328 and 412 marks respectively. The article is illustrated by general and detail drawings, which show clearly the design and mode of construction adopted at the Altenburg tunnel. The same system, the author remarks, is at the present time being made use of in the Remsfeld tunnel, 900 metres (984 yards) in length, on the line of railway from Berlin to Coblenz.—*Abstracts of Institution of Civil Engineers.*

ORDNANCE AND NAVAL.

STEAM STEERING GEAR.—One of our correspondents in Lancashire writes:—"A new steam steering gear, patented by Mr. Harrison, was on Wednesday exhibited for the first time at the works of Messrs. Hodgson and Stead, engineers, Salford. By this invention Mr. Harrison claims to secure to the helmsman a perfect control over the steering engines, and also to do away with the noise which is so objectionable in the apparatus now in use on some of the steamships. The first object is attained by means of a rotary disc valve operated upon by the steering wheel, which cuts off the steam automatically and controls the action of the piston rod to within ½ inch, the engine, in fact, responding instantaneously to every motion of the steering wheel, whilst the noise is obviated by the substitution in the working gear of a worm in the place of the usual wheels and pinions. It is also claimed that the engine will exert the power of twelve men on the rudder, which will be kept steady however rough the action of the sea may be upon it. The working of the apparatus appeared to give satisfaction to a number of gentlemen who inspected it, but I understand it is shortly to undergo a practical test on board ship at Liverpool.

RUSSIAN FAST SAILING STEAMERS.—The Moscow Cruiser Committee has definitely decided that, if possible, no more war steamers for the volunteer fleet are to be purchased out of Russia The question was raised at a recent sitting of the executive branch of the committee at St. Petersburg, under the presidency of Mr. Pobairdonositz, and after the plans and tenders received from shipbuilders and shipowners in every part of the world had been carefully examined, the members unanimously decided that an attempt should be made to encourage the shipbuilding trade of Russia by giving all future orders to native firms. Thereupon Mr. Baird, of Baird's Engineering Works, and Mr. Kazi, the managing director of the Baltic Iron Works, who were both present, undertook to furnish plans of fast-sailing steamers. A temporary contract was drawn up, the main features of which were that the cruisers designed should be corvette shaped, with a spread of 21,000 square feet of canvas, stowage for sufficient coal to enable the vessel to steam sixty days at full speed, and artillery arrangements for the reception of two seven-inch guns and four four-inch mortars. It was understood that in the event of the designs being satisfactory Messrs. Baird and the Baltic Ironworks would each receive an order for at least one cruiser, and that if the donations continued to come in as largely as at present further orders would be given.

THE HECLA; TORPEDO DEPOT SHIP.—The Hecla, screw torpedo depot ship, which arrived at Portsmouth last week from Belfast, and which is expected to be commissioned today by Captain Morgan Singer, lately in command of the Vesuvius and the Glatton, is altogether a novelty, no other ship of the kind being in existence, and is another concession to the necessities of the new mode of conducting actions at sea. She is to be fitted to carry fast torpedo launches and to follow in the wake of a fleet as a depot, ready to despatch her flotilla of small craft for their protection when necessary. She is constructed of iron, and measures 390 ft. in length, and is fitted to carry six 64-pounder muzzle-loading rifled guns, four on the broadside and the rest forward and aft. She is also intended to be armed with torpedoes of the Whitehead kind, and is pierced with a broadside port on each side for ejecting them. The after part below is furnished with lathes and drilling and shaping machines, and will be converted into a floating torpedo workshop. She is divided into a number of various water-tight compartments, not connected, as is the usual mode, with water-tight doors, entrance being gained from the upper and main decks. The element of danger resulting from leaving the connections open in certain eventualities is thus obviated, though it is calculated that the filling of one or two of the compartments with water would not materially affect the behavior of the ship. She is to carry six second class torpedo boats, of which, however, only two have as yet been supplied. Four of these boats will be amidships, the chocks on which they rest running on a tramway. She will also carry a 42 ft. steam launch and a 37 ft steam pinnace. The Hecla will be provided with booms and nets to protect her from an enemy's torpedoes, the booms, when not in use, lying fore and aft against the side of the ship. The captain's cabin and the wardroom are amidships, the wardroom being what, when the ship was built for the merchant service, was intended as a saloon for passengers. She will have a complement of 170 officers and men, and when completed at Portsmouth will be taken to sea for a short period on special service for the purpose of testing her manœuvering and sea qualities.—*London Times.*

STEERING OF SCREW STEAMERS.—The following is the report of the Committee of the British Association, consisting of James R. Napier, F.R.S., Sir W. Thomson, F.R.S., W. R. Froude, F.R.S., J. T. Bottomley, and Osborne Reynolds, F.R.S., Sec., appointed to investigate the effect of propellers on the steering of vessels.

It appears, both from the experiments made by the committee and from other evidence, that the distance required by a screw steamer to bring herself to rest from full speed by the reversal of her screw is independent, or nearly so, of the power of the engines; but depends

on the size and build of the ship, and generally lies between four and six times the ship's length. It is to be borne in mind that it is to the behavior of the ship during this interval that the following remarks apply :—

The main point the committee have had in view has been to ascertain how far the reversing of the screw, in order to stop a ship, did or did not interfere with the action of the rudder during the interval of stopping, and it is as regards this point that the most important light has been thrown on the question of handling ships. It is found an invariable rule that, during the interval in which a ship is stopping herself by the reversal of her screw, the rudder produces none of its usual effects to turn the ship, but that, under these circumstances, the effect of the rudder, such as it is, is to turn the ship in the opposite direction from that in which she would turn if the screw were going ahead. The magnitude of this reverse effect of the rudder is always feeble, and is different for different ships, and even for the same ship under different conditions of loading.

It also appears from the trials that owing to the feeble influence of the rudder over the ship during the interval in which she is stopping, she is at the mercy of any other influences that may act upon her. Thus the wind which always exerts an influence to turn the stem (or forward end) of the ship into the wind, but which influence is usually well under the control of the rudder, may when the screw is reversed become paramount and cause the ship to turn in a direction the very opposite of that which is desired. Also, the reversed screw will exercise an influence, which increases as the ship's way is diminished, to turn the ship to starboard or port according as it is right or left handed; this being particularly the case when the ships are in light draught.

These several influences, the reversed effect of the rudder, the effect of the wind, and the action of the screw, will determine the course the ship takes during the interval of stopping. They may balance, in which case the ship will go straight on, or any one of three may predominate, and determine the course of the ship.

The utmost effect of these influences when they all act in conjunction, as when the screw is right handed, the helm starboarded, and the wind on the starboard side, is small as compared with the influence of the rudder as it acts when the ship is steaming ahead. In no instance has a ship tried by the committee been able to turn with the screw reversed on a circle of less than double the radius of that on which she would turn when steaming, ahead. So that even if those in charge could govern the direction in which the ship will turn while stopping, she turns but slowly, whereas, in point of fact, those in charge have little or no control over this direction, and, unless they are exceptionally well acquainted with their ship, they will be unable even to predict the direction.

It is easy to see, therefore, that if on approaching danger the screw be reversed, all idea of turning the ship out of the way of danger must be abandoned. She may turn a little, and those in charge may know in what direction she will turn, or may even, by using the rudder in an adverse manner, be able to influence this direction, but the amount of turning must be small and the direction very uncertain. The question, therefore, as to the advisability of reversing the screw is simply a question as to whether the danger may be better avoided by stopping or by turning. A ship cannot do both with any certainty.

Which of these two courses is the better to follow must depend on the particular circumstances of each particular case; but the following considerations would appear to show that when the helm is under sufficient command there can seldom be any doubt.

A screw steamship when at full speed requires five lengths, more or less, in which to stop herself ; whereas, by using her rudder, and steaming on at full speed ahead, she should be able to turn herself through a quadrant without having advanced five lengths in her original direction. That is to say, a ship can turn a circle of not greater radius than four lengths, more or less (see *Hankow*, *Valetta*, *Barge*) so that if running at full speed directly on to a straight coast, she should be able to save herself by steaming on ahead and using her rudder after she is too near to save herself by stopping; and any obliquity in the direction of approach or any limit to the breadth of the object ahead is all to the advantage of turning, but not at all to the advantage of stopping.

There is one consideration, however, with regard to the question of stopping or turning, which must, according to the present custom, often have weight, although there can be but one opinion as to the viciousness of this custom. This consideration is the utter inability of the officers in charge to make any rapid use of their rudder so long as their engines are kept on ahead. It is no uncommon thing for the largest ships to be steered by as few as two men. And the mere fact of the wheel being so arranged that two men have command of the rudder, renders so many turns of the wheel necessary to bring the rudder over that even where ready help is at hand it takes a long time to turn the wheel round and round so as to put a large angle on the rudder.

The result is, that it is often one or two minutes after the order is heard before there is any large angle on the rudder, and of course, under these circumstances, it is absurd to talk of making use of the turning qualities of a ship in case of emergency. The power available to turn the rudder should be proportional to the tonnage of the vessel, and there is no mechanical reason why the rudder of the largest vessel should not be brought hard over in less than 15 seconds from the time the order is given. Had those in charge of steamships efficient control over their rudders, it is probable that much less would be heard of the reversing of the engines in cases of imminent danger.

BOOK NOTICES.

PRANG'S STANDARD ALPHABETS. Boston: L. Prang & Co. Price $5.00. For sale by D. Van Nostrand.

This collection of ornamental alphabets for the use of decorators, designers and draughtsmen, is in excellent style.

We are glad to see that in the more florid ornamenting, the letters are yet plainly distinguishable, which was not the case in the letter books of former years.

In addition to the alphabets, there are some examples of topographical mapping in colors, and the Coats of Arms of the States also in colors. Altogether, it is an elegant and useful volume.

A Practical Treatise on Casting and Founding. By N. E. Spretson. London: E. & F. N. Spon. Price $7.00. For sale by D. Van Nostrand.

This book is for the artisan only. It affords a complete description of all the details of casting and founding, iron, steel, brass and bronze.

The illustrations alone cover eighty-four full page plates of royal octavo size.

The work is divided into thirty chapters, but, without enumerating these, the following list of subjects may be mentioned, as embracing the matter of the book in their order:

Pig Iron; Furnaces and their Accessories; Moulding and Casting; Foundries and their Equipments; Steel, Brass, Bronze and Bell Founding; Tables and Notes.

There are 400 pages of text, besides the the plates mentioned above.

Van Nostrand's Science Series, No. 39.

A Hand Book of the Electro-Magnetic Telegraph. By A. E. Loring. New York: D. Van Nostrand. Price, boards, 50 cts.; cloth, 75 cts.; half mor., $1.00.

Instruction books for students in telegraphy have heretofore been encumbered with material which was of little or no aid to the beginner.

A small hand book of first principles has been needed to prepare the learner for the preliminary work as well as for the understanding of the complete treatises upon this comparatively new branch of industry.

For a student may be well up in electricity and magnetism of the schools and colleges, and entirely unlearned, not only in the application of the principles of these sciences, but of the technical language of the telegraph room.

Mr. Loring is a practical telegrapher, and has presented in the most concise form the leading facts and formulas which are in constant requisition in telegraphing.

Without being severely technical, or even rigorously scientific, he enables the student to make a good *reconnaissance* of this field of labor, and affords him such hints as will enable him to fill in his details of information from the more complete sources.

The work is divided into parts as follows:

Part 1, Electricity and Magnetism; Part 2, the Morse Telegraph; Part 3, Batteries; Part 4, Practical Telegraphy; Part 5, Construction of Sines.

Appendix containing suggestions and exercises for learners.

The illustrations are good, and are distributed throughout the text.

Coal and Iron in all Countries of the World. By J. Pechar. London: Simpkin, Marshall & Co. Price $2.00. For sale by D. Van Nostrand.

This is largely statistical as the title implies. It is compiled from the latest sources, and is one of the reports made up from materials furnished by the Paris Exposition.

The report deals with the character of the coal and iron deposits, methods of working, and amount of home consumption and export.

The introduction under the head of General Remarks, discusses the causes of the great depression in trade, and adds more valuable statistical information regarding the railway systems of the world.

A History of the Growth of the Steam Engine. By Robert H. Thurston, A.M., C.E. New York: D. Appleton & Co. Price $2.50. For sale by D. Van Nostrand.

This is the latest addition to the "International Scientific Series" of these enterprising publishers, and judging by the naturally widespread interest in the subject, we may expect that it will be regarded as the most important of the series by a large plurality of scientific readers.

The preparation of such a history could not have been assigned to better hands. Taste, early education and professional training have all tended to prepare the talented author for this work, and his experience furthermore as an instructor of young men has specially fitted him to relate the story of the growth of this great agent of civilization, so that the merest tyro can enjoy it, and the scientist regard it as valuable.

Not a small portion of the labor and expense of the work, either to author or publisher, is represented by the illustrations, which are very numerous and exceedingly good.

The book is sure of a multitude of readers.

The Analytical Theory of Heat. By Joseph Fourier. Translated by Alexander Freeman, M.A. Cambridge: University Press. Price $7.00. For sale by D. Van Nostrand.

One of those works involving the higher analyses to an extent that is specially attractive to the mathematician.

When great laws of phyics and their resultant phenomena are expressed by aid of triple integrals, the mathematician first feels an interest in them, and then only proposes to aid in the work of developing.

The department of Heat has long since become a favorite field for the analyst, and the work before us is the most complete evidence of it.

The topics treated by chapters are:

1. Introductory; Equation of the Movement of Heat; Propagation of Heat in an Infinite Rectangular Solid; Linear and Varied Movement of Heat in a Ring; Propagation of Heat in a Solid Sphere; Movement of Heat in a Solid Cylinder; Propagation of Heat in a Rectangular Prism; Movement of Heat in a Solid Cube; The Diffusion of Heat.

It is a well printed volume of 466 pages, royal octavo.

GEOGRAPHICAL SURVEYING. By FRANK DE YEAUX CARPENTER. New York: D. Van Nostrand. Price 50 cts.

This little treatise, written originally, as it appears, for the purpose of presenting to the Geological Commission of Brazil a general sketch of the plan proposed for mapping the immense territory of that Empire, in connection with the Geological Survey organized by the late Prof. Hartt, appears in Van Nostrand's excellent Science Series, and forms a useful contribution to the popular science literature of our country. Its author, formerly connected with the geographical surveys of the Engineer Department under Lieut. Wheeler, proposes the name Geographical rather than Topographical Surveying, to distinguish the kind of work necessary for covering a large extent of comparatively unexplored country (when thousands of square miles must be mapped in a season) from the slow and detailed surveying which indicates every man's farm and house, as carried on by the Government surveys of Europe. While the former should be based on determinations of primary points no less accurate than the latter, the intermediate details are to be sketched in by methods of approximation, which will present with sufficient accuracy the general physical features of the region surveyed, and the method may therefore be called *geo*-graphical rather than *topo*-graphical, as describing the surface of the globe, rather than of limited regions or places. This has been the system pursued by our various Government geological surveys in the Rocky Mountain region; and the author mentions the work of Hayden's, Powell's and Wheeler's surveys, from whose experience he has drawn his material, but neglects to give credit to the forerunner and, in one sense, the originator of all these, that of the 40th Parallel under Mr. Clarence King. As he avoids all formulas, and presents his subject with clearness and precision, the work will be found pleasant reading for all interested in geography.—*The Nation.*

THE ELEMENTS OF GRAPHICAL STATICS AND THEIR APPLICATIONS TO FRAMED STRUCTURES, WITH NUMEROUS PRACTICAL EXAMPLES OF CRANES, BRIDGE, ROOF AND SUSPENSION TRUSSES, ETC. By A. JAY DUBOIS, C.E., Ph.D. New York. 1875. John Wiley & Son.

In the course of a review of DuBois' "Graphical Statics," published in the *Zeitschrift des Ver. Deutsch Ing*, the writer says:

"This surprisingly long title is followed by a preface of ten closely-printed pages, which contains notices valuable to the student while using the book. The table of contents, of twelve pages of fine print, is preceded by a four-page note, 'Elements of Graphic Statics,' intended especially for student and teacher. Then follows, under the title 'Introduction,' an excellent and exact translation (!), including references, of the capital work of our German colleague, Dr. J. Weyrauch, '*Ueber die Graphische Statik,' Leipsig: Verlag von Teubner.* The title of the first chapter, 'Historical and Critical,' is accompanied by an asterisk with the reference 'Weyrauch, U. S. W.'; and in his preface DuBois says: 'For the historical and critical introduction we are indebted, a few alterations excepted, to the pen of Weyrauch. It will be useful, &c., &c.' As regards the 'few alterations' of DuBois, we have not been able to discover them, except in the omission of several scientific references of Weyrauch. The American reader is led to infer from DuBois' method of reference that only one page of his 'Introduction' is taken from Weyrauch; when, in fact, as I find after a thorough examination, there are twenty-seven pages of close translation.*

"What particular use was made of Culmann, Mohr, Ritter, Winkler and Reuleaux, and how much Cremona, Favaro and others were studied, after the entire literature had been collated by Weyrauch's diligence for the benefit of the translator, we shall not determine: but to DuBois belongs the credit of industry in collecting, and of the introduction of practical examples."

The reviewer then speaks favorably of the work as a record of the progress of research in this department in Germany, Italy, France and England. Concerning the plates, he says: "Entire plates show a lack of the care in delineation which is required in a work like this."

A HANDBOOK OF PATENT LAW OF ALL COUNTRIES. By WILLIAM P. THOMPSON, C.E. London: Stevens & Sons; New York: Van Nostrand, 1878.

The author of this little book is the head of a patent agency in Liverpool, and therefore writes with the advantage of practical experience. The book has no pretension to be regarded as a complete treatise on patent law; it is rather a guide to patentees, and in many respects an *aide memoire* to practitioners. The first part is naturally devoted to a summary of the English law, in which the progressive steps, with their cost, towards the completed patent, are clearly explained. The suggestions and observations of the author, as for instance those under the head of preliminary "Searches," are generally practical, but there are a few slips which should be corrected in a subsequent edition. At the outset his statement of the principle of our patent law as "a simple contract between the Crown, on behalf of the nation at large, and the inventor," is not legally correct. This view of the relationship of Crown and inventor was judicially repudiated in the celebrated action of *Feathers* vs. *the Queen,* in which Cockburn, C.J., speaking for the Court, explained the grant of a patent to be a mere act of the prerogative, coupled with a condition, namely, full publication by the patentee. Again, Mr. Thompson says of joint patentees that "each can grant licenses independently of the other," omitting to point out that it is by no means clear that the royalties will not belong to both. The well-known case of *Mathers* vs. *Green* decided that a joint patentee could work the whole invention for his own benefit without accounting to his fel-

* In the same way Reye, *Geometrie der Lage,* and Bauschinger, *Graphische Statik,* are employed; of course with references.

low-patentee ; but that decision expressly left open the case of profits to be derived from the grant of licenses. Under the head of "Infringements," Mr. Thompson writes thus: "Patent trials are proverbially expensive in England, the law and procedure being apparently framed with the special object rather of putting fees into the lawyers' pockets than of doing justice promptly and cheaply. As the cases have to be fought out by lawyers, almost invariably utterly ignorant of the technicalities of the case, and before judges, learned only in the law, the probabillty of obtaining justice, even with a long purse, is not extravagantly great. Often, too, when the case comes to a hearing, and nearly all the expenses of the lawsuit have been incurred, the court, conscious of its poor qualification for deciding scientific and technical matters, persuades the parties to put the matter to arbitration." We are surprised to find any one with any pretence to experience writing in this strain. Surely Mr. Thompson must know that the actual cost of preparing pleadings and bringing the action to issue is trifling to a degree compared with the costs of witnesses and the collection of evidence—costs unavoidable so long as novelty and utility are essential to a patent. He might as justly say that the law and precedure were framed with the object of benefiting professional expert witnesses—one at least of whom, by the way, well known for his ability, is actually a patent agent. That our courts are incapable of dealing with technical cases is amply disproved by the way in which the celebrated Plimpton skate was handled by Bench and Bar in the many actions in which it was involved. As for arbitration as a solution of an infringement queston, we can only say that if a party or his adviser is sufficiently foolish to consent to such a course—and presumably Mr. Thompson has met with a case, we have not—and so preclude himself from judicial assistance, he has only himself to blame. No court in this country declines, or can decline, to try such an action, if properly presented for its decision. Moreover, it is not the fact, as stated further on, that the court rarely makes use of its power to grant an interim or "preliminary" injunction until the trial is decided. This is true in the case of new and untried patents, but where the validity of a patent has been established in another action, such an injunction is almost of course. A great part of the book is occupied by a very useful analysis of foreign laws. So far as we have tested this digest it is clear and correct. We would, however, suggest a few additions. In every case the date, or other reference, to the particular law should be given, and the Government taxes should be inserted. This latter is not always done in the book before us, though it is true Mr. Thompson gives invariably the approximate cost of obtaining the patent—including therein the agent's fees of course. Moreover, it should be stated with more precision whether preliminary examination is or is not required. Such information for instance, is wanting here under the head of "Belgium." The work concludes with "Hints for Inventors," "How to Sell a Patent," and some well-merited strictures on a certain class of "Patent Agents." The defects we have indicated do not seriously affect the utility of the book. It contains a good deal of information in a small space, and will be found useful by a large section of our readers.—*The Engineer.*

MISCELLANEOUS.

HEIGHT OF JETS.—J. F. Flagg, C. E., gives, in a communication to *Engineering News*, a new formula for jets of water.

It is

$$h = H - .00127\,H^2$$

H being the head of water, and h the height of the jet.

GLASS-CLOTH.—*Gastach*, or glass-cloth, is a name given by Dr. Hirzel, of Leipsic, to a gas and water-tight stuff, which he has recently patented. This is produced by placing a large smooth piece of so-called gutta-percha paper between two pieces of some not too coarse and dense material—*e.g.*, shirting (undressed),—and then passing the arrangement between heated rollers. The outer pieces of the shirting combine in the most intimate way with the enclosed gutta percha to form a material which is impenetrable by gas and water. It may be made still denser and more resistant by being coated on both sides with, *e.g.*, copal lac. The material is said to be well adapted to form gas-tight membranes for regulators of pressure of compressed gas-bags, or sacks for dry gas-meters, as also dry gas-reservoirs.

A NEW METHOD OF DETERMINING THE HEAT VALUE OF FUEL.—With regard to the important question of the heat value of fuel, it has been proved that conclusions from the results of elementary analysis are very uncertain, and, also, that little reliance can be placed on direct evaporization experiments. In a recent paper in *Die Chemische Industrie*, Dr. Weyl points out the faults of these methods, and recommends, as preferable, decomposition of the fuel by dry distillation and analytical determination of the solid, liquid, and gaseous products of decomposition. In this method the accident of too small a sample being used is avoided, as also too great pulverization and drying at high temperature and the decomposing action of atmospheric oxygen, which is therewith connected, and the whole of the coke is weighed, and its carbon, hydrogen, and mineral constituents determined. The water, tar, and gas that are formed are measured, and their heat of combustion ascertained with the aid of data that have been supplied by Favre and Silbermann and Deville. The final result will, of course, exceed the true combustion value of the coal by the amount of heat equivalent to the work of decomposition into coke, tar, and gas. The decomposition of the coal should be done as quickly as possible, and at a high temperature.

CONFIRMATION OF THE DISCOVERY OF THE PLANET VULCAN.—In a communication addressed to Rear-Admiral Rogers, Supt. of the U. S. Naval Observatory, under the date of August 2nd, Prof. J. C. Watson, of Ann Arbor,

confirms his reported discovery of the interior planet, to which we alluded in last week's issue, in discussing the successful results of the late eclipse expeditions. The letter contains, likewise, a summary of the observations upon which the announcement of the discovery is based, and which, coming from so accomplished an astronomer as Prof. Watson, leave no reasonable doubt as to their genuineness and of the accuracy of his inferences.

With Mars' moons, and the long-sought-for Vulcan, as the contribution of America to this department of science within two years, our astronomers have earned more than their share of triumphs. The letter is as follows:

"I have the honor to report that at the time of totality I observed a star of the four-and-a-half magnitude, in right ascension, 8 hours, 26 minutes declination, 18 degrees north, which is, I feel convinced, an intra-mercurial planet. I observed with a power of forty-five, and did not have time to change the power so as to enlarge the disk. There is no known star in the position observed, and I did not see any elongation such as ought to exist in the case of a comet very near the sun. I will hereafter report to you more fully in regard to the observations made. The appearance of the object observed was that of a ruddy star of the four-and-a-half magnitude. The method which I adopted prevents the possibility of error from wrong circle readings; besides, I had memorized the Washington chart of the region, and no such star was marked thereon. By comparison with the neighboring stars on Argelander's scale, the magnitude of the planet would be fifth, although my direct estimate at the time of the observation was four and a half, as stated."—*Polytechnic Review.*

NEW FIRE ENGINES.—The Metropolitan Fire Brigade have just added to the plant of the new chief station, in the Southwark Bridge road, two of the most improved form of light steam fire-engines, specially suited for rapid transmission to a fire. These engines were tested on the premises of the makers, (Messrs. Shand, Mason & Co.), in the presence of Captain Shaw and his officers. Various improvements have been introduced; by means of those in the boiler, steam was raised from cold water to 100 lbs. on the square inch in 6½ minutes, this being an acceleration of time by about three or four minutes as compared with the engines previously in use—a most essential point, considering the necessity of bringing a jet of water to bear upon the fire in the shortest possible time. The increasing height to which warehouses and public buildings are now carried in London rendering it necessary for increased pressure in the water jet, has been met in these engines by an increased area of steam cylinder as compared with the water cylinder, while the difficulty of the man in charge of the jet being able to shut it off entirely to avoid unnecessary damage by water, or from other causes, without the roundabout way of sending a messenger to the engine, which may be in another street, has been met by the adoption of a patent self-acting apparatus by which the jet may be entirely closed at the building on fire without interfering with or stopping the working of the engine. This is accomplished by a special hydraulic safety-valve regulated by a spring balance, which allows all excess of pressure to be relieved by passing the water to the suction-pipe. The first of this improved form of engine has been sent by the makers to the Paris Exhibition.

IMPORTANCE OF GEOLOGICAL KNOWLEDGE TO ENGINEERS.—The value of at least an elementary knowledge of geology to the engineer cannot be over estimated. It is applicable in nearly every work upon which he may be engaged. In the projection of earthworks, tunnels, drainage, water supply and the selection of sites for any structure, success depends largely upon geological considerations.

The engineer should be familiar with the laws governing rock deposition and metamorphism; he should know how rocks are fractured; upheaved and faulted; he should know the characteristics of such as enter his work, and he should know their order of succession.

The stability of earthworks depends quite as much upon the character of the underlying rock as upon careful construction. A deep cut may change a natural drainage, and serious results might follow. The trickling of water through a severed bed of marl or sand may produce a serious earth slip. The dip of the beds should be ascertained.

Railroad and canal embankments and cuttings could oftentimes be more wisely located at a great saving of cost. True, circumstances may compel their location at points not geologically economical, but the engineer who can foresee the evils that might follow from such location, will best be enabled to prevent disaster. Enormous expense has attended repairs resulting from the ignorance or neglect of such anticipation. More than $100,000 were required to remedy the slips in the Breval cut (3000 ft.), on the Paris & Cherbourg railway.

In tunneling, a knowledge of stratification is absolutely necessary, for without it no true estimate can be made. Even the genius and skill which projected that grand work, the St. Gothard tunnel, have had their brilliancy clouded by the blundering miscalculation of its cost. Want of thorough geological inquiry seems evident.

The engineer should know what probable rock will be found at a certain depth, whether or not water may be expected, and if so, under what pressure.

The location of reservoirs should not be determined by merely superficial observation. The suitability of the underlying stratum should be settled. The fact that certain rocks allow water to pass freely through them, while others are almost absolutely impermeable, is as important in its application to rocks out of sight as to those at the surface. Land slips teach us this.

More time might be expended economically in the careful examination of the surface rock; it might be permeable without seeming so; it might be connected with a permeable stratum containing injurious soluble matter; or there might be a near limit to its retentive power. A little attention in this direction might be as profitable as good construction.

VAN NOSTRAND'S
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TRANSMISSION OF POWER BY COMPRESSED AIR.

By ROBERT ZAHNER, M. E.

Contributed to Van Nostrand's Magazine.

II.

CHAPTER IV.

THE THERMODYNAMIC EQUATIONS APPLIED TO PERMANENT GASES.

I.

DETERMINATION OF THE SPECIFIC HEAT AT CONSTANT VOLUME.

Forming, from eq. (3), the partial differentials:

$$\left(\frac{dt}{dp}\right)=\frac{\mathrm{V}}{\mathrm{R}},\left(\frac{dt}{dv}\right)=\frac{p}{\mathrm{R}},\frac{d^2t}{dp.dv}=\frac{1}{\mathrm{R}},$$

and substituting in eqs. (20) and (21), we have:

$$(c-c')=\frac{1}{\mathrm{J}}\mathrm{R}, \qquad (22)$$

and $$\Phi(t)=\frac{p\mathrm{V}}{\mathrm{R}}=(a+t) \qquad (23)$$

(22) gives, $c'=c-\frac{1}{\mathrm{J}}\mathrm{R}=.238-\frac{96.0376}{1389.6}$
$=.169$

which is the specific heat at constant volume for atmospheric air.

II.

INTERNAL HEAT.

Placing eqs. (12) and (15) equal to each other and substituting the value of c from (22), we have:

$$\left(\frac{du}{dp}\right)dp+\left(\frac{du}{dv}\right)dv=c'(vap+pdv)\frac{1}{\mathrm{R}}=du,$$

according to eq. (11).

Integrating, and substituting for R its value $\frac{pv}{\tau}$ we have,

$$u=c'\tau-u_0$$

or $$u-u_0=c'\tau \qquad (24)$$

which shows that the internal heat for every degree of temperature is increased by a quantity c' (.169), and the increase of the internal heat of a gas passing from 0°C. to t°C. is always the same, whatever variations its pressure may have undergone in this passage, the volume having been kept constant.

III.

QUALITY OF HEAT SUPPLIED.

The partial differentials formed from eq. (3) placed in (15) gives:

$$d\mathrm{Q}=\frac{c'vdp+cpdv}{\mathrm{R}} \qquad (25)$$

which is integrable only when we have a given relation between p and v.

1. At constant volume; make $dv=o$, v being constant. Then

$$Q=\int_{p_0}^{p}\frac{c'vdp}{R}=\frac{c'v(p-p_0)}{R}=c'(\tau-\tau_0) \quad (25a)$$

which defines the specific heat at constant volume.

2. At constant pressure; here $dp=o$, and eq. (25) gives:

$$Q=\frac{cp(v-v_0)}{R}=c(\tau-\tau_0) \quad (25b)$$

IV.

EXPANSION AT A CONSTANT TEMPERATURE.

To find the work done by a gas expanding *isothermally*, (that is, the absolute temperature is maintained at a constant value), we must satisfy Boyle's law and write:

$$pv=p_0v_0=\text{constant};$$

hence $pdv+vdp=o$; or, $vdp=-pdv$. Substituting this in (25),

$$dQ=\frac{(c-c')pdv}{R}=\frac{1}{J}pdv;$$

Introducing p from eq. (3),

$$da=\frac{1}{J}R(a+t)\frac{dv}{v},$$

and,

$$Q=\frac{1}{J}R(a+t)\int_{v_0}^{v}\frac{dv}{v}=\frac{1}{J}R(a+t)\log.\frac{v}{v_0}.$$

$$=\frac{1}{J}p_0v_0\log.\frac{v}{v_0} \quad (26.)$$

Let W=the work done; then

$$W=p_0v_0\log.\frac{v}{v_0}.* \quad (26a.)$$

the ordinary form for permanent gases.

V.

EXPANSION IN A PERFECTLY NON-CONDUCTING CYLINDER.

If a gas expand *adiabatically*, (*i.e.*, without any passage of heat either into the gas from without or out of the gas into other substances) $dQ=o$ in eq. (25), and we have,

$$c'vdp+cpdv=o.$$

Writing for $\frac{c}{c'}$ its value r, and integrating, we have

* The logarithms, it is seen, are taken in the Naperian system.

$$\int_{p_0}^{p}\frac{dp}{p}+r\int_{v_0}^{v}\frac{dv}{v}=\log.\frac{p}{p_0}+r\log.\frac{v}{v_0}=o$$

$$=\log.\frac{p}{p_0}+\log.\frac{v^r}{v_0^r}=o$$

or, $\log.\frac{p}{p_0}=\log.\frac{v}{v_0}\times(-r)=\log.\frac{v_0^r}{v^r}$

hence, $pv^r=p_0v_0^r=\text{constant};$ (27)

an equation which expresses the variation of pressure as a function of volume when the expansion or compression is *adiabatic.*

The external work performed during a finite expansion is denoted by

$$W=\int_{v_0}^{v}pdv=\int_{v_0}^{v}p_0v_0^r\frac{dv}{v^r}=p_0v_0^r\int_{v_0}^{v}v^{-r}\,dv \quad (27a)$$

$$=\frac{p_0v_0^r}{r-1}\left(\frac{1}{v_0^{r-1}}-\frac{1}{v^{r-1}}\right)=\frac{p_0v_0}{r-1}\left\{1-\left(\frac{v_0}{v}\right)^{r-1}\right\} \quad (28)$$

Since no heat is received from without, the thermal equivalent of the work must be estimated as *internal* heat. If, now, τ_0 and τ are the initial and final absolute temperatures, the decrease in internal heat will be

$$c'(\tau_0-\tau).$$

Hence we must have,

$$c'(\tau_0-\tau)=\frac{1}{J}\frac{p_0v_0}{r-1}\left\{1-\left(\frac{v_0}{v}\right)^{r-1}\right\} \quad (29)$$

Eq. (27) gives $\frac{pv^r}{p_0v_0^r}=1$; multiplying both members by $\frac{v_0^{r-1}}{v^{r-1}}$ we have,

$$\frac{pv}{p_0v_0}=\left(\frac{v}{v_0}\right)^{r-1}=\frac{a+t}{a+t_0}=\frac{\tau}{\tau_0}; \quad (30)$$

also,

$$\frac{v_0^r}{v^r}=\frac{p}{p_0},\text{ and }\frac{v_0}{v}=\left(\frac{p}{p_0}\right)^{\frac{1}{r}}.$$

hence,

$$\left(\frac{v_0}{v}\right)^{r-1}=\left(\frac{p}{p_0}\right)^{\frac{r-1}{r}}=\frac{a+t}{a+t_0}=\frac{\tau}{\tau_0} \quad (31)$$

Substituting in (28) the values of p_0v_0 from (3) and $\left(\frac{v_0}{v}\right)^{r-1}$ from (31) we obtain:

$$W=\frac{R(a+t_0)}{r-1}\left\{1-\left(\frac{p}{p_0}\right)^{\frac{r-1}{r}}\right\} \qquad (32)$$

a form often used $\frac{r-1}{r}=.2908$.

VI.

Variations in the temperature of a gas during expansion or compression in a perfectly non-conducting cylinder.

Placing the second members of $p_0v_0=$ R $(a+t_0)$, $r=\frac{c}{c'}$, and $J=\frac{c-c'}{R}$ in eq. (29) we get:

$$t_0-t=\tau\left\{1-\left(\frac{v_0}{v}\right)^{r-1}\right\}, \qquad (33)$$

which is thus interpreted:

The decrease in temperature (during an expansion from v_0 to v) is proportional to the initial absolute temperature.

The already established relation,

$$\frac{\tau}{\tau_0}=\left(\frac{v_0}{v}\right)^{r-1}$$

expresses the final temperature as a function of the volumes; and if we know the initial and final pressures, the final temperature is expressed as a function of these pressures as follows:

$$\frac{a+t}{a+t_0}=\frac{\tau}{\tau_0}=\left\{\frac{p}{p_0}\right\}^{\frac{r-1}{r}}$$

CHAPTER V.

Thermodynamic Laws Applied to the Action of Compressed Air.*

I

FUNDAMENTAL FORMULAS.

The four equations formulating the law for the expansion and compression of dry air, are, as we have established them,

$$\frac{pv}{a+t}=Rw=\frac{pv}{\tau}=J(c-c')w \qquad (34a)$$

$$\frac{p}{p_0}=\left\{\frac{v_0}{v}\right\}^{r}=\left\{\frac{v_0}{v}\right\}^{\frac{c}{c'}} \qquad 34\ b)$$

$$\frac{\tau}{\tau_0}=\left\{\frac{v_0}{v}\right\}^{r-1}=\left\{\frac{v_0}{v}\right\}^{\frac{c}{c'}-1} \qquad (34c)$$

$$\frac{\tau}{\tau_0}=\left\{\frac{p}{p_0}\right\}^{\frac{r-1}{r}}=\left\{\frac{p}{p_0}\right\}^{\frac{\frac{c}{c'}-1}{\frac{c}{c'}}} \qquad (34d)$$

* The subject of this chapter is very ably treated by M. Mallard, in the "Bulletin de la Société de l' industrie minerale," tome xii, page 615, to whom the writer is greatly indebted.

These expressions sum up the relations existing between the *pressure, volume* and *absolute temperature* of a weight of air w compressed or expanded in a perfectly non-conducting cylinder.

p_0, τ_0, and v_0 have reference to the *initial* state of the weight of air considered, p, τ and v corresponding to the final state.

The following table is that of MM. Mallard and Pernolet. It gives for convenient values of $\frac{p}{p_0}$ the corresponding values of $\frac{\tau}{\tau_0}$, &c. The tabular differences facilitate interpolation.

(*See Table on following page.*)

II.

WORK SPENT IN COMPRESSING AIR.

The compressing-cylinder being supposed perfectly non-conducting as to heat, our machine may be called a "Reversible Engine;" for by reversing the process of compression under exactly the same conditions, we get back the exact amount of work spent in the compression.

The net work necessary to compress a weight of air w, taken from a reservoir (as the atmosphere) in which the pressure p_0 is kept constant, and to force it into another reservoir in which the pressure is constantly p_1, is made up of the following parts:—

1. The work of compression:
2. Diminished by the work due to the pressure p_0 of the first reservoir (the atmosphere); this work is $p_0\,v_0$, v_0 being the volume of weight w under pressure p_0 and at the temperature t_0:
3. Increased by the work necessary to force the compressed air into the receiving reservoir; this is given by the expression $p_1\,v_1$, v_1 being the volume of a weight of air w at the pressure p, and temperature t_1.

As no heat passes between the air and external bodies, the thermal equivalent of the work, according to the mechanical theory of heat, is the difference between the quantity of internal heat possessed by the air at its entrance into the cylinder, and that possessed by it its exit.

The heat possessed by the air at its entrance into the cylinder is,

$$wc^1\tau_0;$$

TABLE I.

$\frac{p}{p_0}$	$\frac{\tau}{\tau_0}$		$\frac{\tau_0}{\tau}$		$1-\frac{\tau_0}{\tau}$	$\frac{v_0}{v}$		$\frac{v}{v_0}$		$\frac{t_a}{t}$	
	Numbers.	Differences.	Numbers.	Differences.	Numbers.	Numbers.	Differences.	Numbers.	Differences.	Numbers.	Differences.
1.2	1.0543	481	.9485	415	.0515	1.1382	1317	.8786	911	.793	78
1.4	1.1024	436	.9070	344	.0930	1.2699	1262	.7875	712	.695	53
1.6	1.1416	439	.8762	293	.1274	1.3961	1218	.7163	575	.642	39
1.8	1.1859	367	.8433	254	.1567	1.5179	1179	.6588	475	.603	32
2	1.2226	343	.8179	223	.1821	1.6358	1145	.6113	400	.571	25
2.2	1.2569	321	.7956	198	.2044	1.7503	1116	.5713	342	.546	22
2.4	1.2890	303	.7758	178	.2242	1.8619	1088	.5371	297	.524	19
2.6	1.3193	187	.7580	161	.2420	1.9707	1065	.5074	260	.505	17
2.8	1.3480	272	.7419	147	.2581	2.0772	1043	.4814	230	.488	15
3	1.3752	260	.7272	124	.2728	2.1815	1023	.4584	205	.473	13
3.2	1.4012	248	.7138	125	.2862	2.2838	1005	.4379	185	.460	12
3.4	1.4260	238	.7013	116	.2987	2.3843	587	.4194	167	.448	10
3.6	1.4498	230	.6897	107	.3103	2.4830	972	.4027	151	.438	10
3.8	1.4728	220	.6790	100	.3210	2.5802	957	.3876	139	.428	9
4	1.4948	213	.6690	94	.3310	2.6759	943	.3737	127	.419	9
4.2	1.5161	206	.6596	89	.3404	2.7702	930	.3610	117	.410	8
4.4	1.5367	200	.6507	81	.3493	2.8632	118	.3493	111	.402	7
4.6	1.5567	193	.6424	79	.3576	2.9550	906	.3384	101	.395	7
4.8	1.5760	188	.6345	75	.3655	3.0456	896	.3283	93	.388	6
5	1.5948	865	.6270	322	.3730	3.1352	4333	.3190	388	.382	27
6	1.6813	769	.5948	260	4052	3.5685	4129	.2802	290	.355	19
7	1.7582	694	.5684	217	.4512	3.9814	3858	.2512	227	.334	19
8	1.8276	636	.5471	183	.4529	4.3772	3817	.2285	184	.317	14
9	1.8712	588	.5288	159	.4712	4.7589	3697	.2101	151	.303	12
10	1.9500	544	.5128	141	.4871	5.1286	3583	.1950	126	.291	10
11	2.0044	512	.4988	124	.5012	5.4869	3484	.1824	111	.281	9
12	2.0556	484	.4864	111	.5136	5 8353	3430	.1713	95	.272	9
13	2.1040	457	.4753	101	.5247	6.1783	334	.1618	83	.263	7
14	2.1497	434	.4652	92	.5348	6.5123	3273	.1535	73	.256	6
15	2.1931		.4560		.5440	6.8396		.1462		.250	

The internal heat at its exit is,

$$wc^1\tau_1.$$

Hence the work of compression is,

$$Jwc^1\tau_1 - Jwc^1\tau_0 = Jwc^1(\tau_1 - \tau_0),$$

and the net work is,

$$W_1 = Jc^1w(\tau_1 - \tau_0) - p_0v_0 + p_1v_1.$$

Substituting for p_0v_0 and p_1v_1 their values from eq. (34a) we have,

$$W_1 = Jwc(\tau_1 - \tau_0) \qquad (35)$$

an equation perfectly general for dry atmospheric air.

III.

WORK OBTAINABLE FROM THE COMPRESSED AIR.

If, by any process, we cause a weight of air w to pass from one reservoir, in which there is a constant pressure p_0, into another reservoir, in which there is a constant pressure p_1, and thereby consume an amount of work W_1, the same weight of air w (supposing the air to remain in the same physical conditions) will restore the amount of consumed work W_1 in passing back from the second reservoir into the first. These are the conditions of a perfect thermodynamic engine.

The work theoretically obtainable from compressed air is therefore, eq. (35),

$$W_1 = Jwc(\tau_1 - \tau_0)$$

an equation which shows how important it is to take into account the initial and final temperature of the air.

IV.

THE THEORY OF COMPRESSION.

1. The work necessary and the volume of the Compressing-Cylinder. Neglecting

all dead spaces and resistances, we can easily calculate, by the aid of our formulas and of table I, the work necessary to compress to a pressure p_1 a weight of air w, taken at a pressure p_0 and a temperature τ_0, as well as the volume to be given to the cylinder of the compressor to compress a given weight of air w per second, the time T being given in seconds.

Our formulas are :

$$W_1 = Jwc(\tau_1 - \tau_0) = Jwc\tau_0 \left\{ \frac{\tau_1}{\tau_0} - 1 \right\}, \quad (35a)$$

when a final temperature τ_1, which is not to be exceeded, is assumed, the value of $\frac{\tau_1}{\tau_0}$ being obtained as a function of $\frac{p_1}{p_0}$ from table 1, or from an adiabatic curve.

$$W_1 = Jwc \left\{ \left(\frac{p_1}{p_0}\right)^{\frac{r-1}{r}} - 1 \right\}, \quad (35b)$$

when a pressure p_1, to which we wish to attain, is assumed.

$$W_1 = p_0 v_0 \frac{r}{r-1} \left\{ \frac{\tau_1}{\tau_0} - 1 \right\}, \quad (35c)$$

an equation employed when we wish to find W_1 as a function of the volume v_0 of the air instead of as a function of its weight. This equation is obtained by substituting in eq. (35*a*.) the value of τ_0 from eq. (34*a*.), and r for $\frac{c}{c'}$.

From eq. (34*a*.) we have,

$$Y_1 = Rw\frac{\tau^0}{p_0} \times T, \quad (36)$$

an equation for the volume of the cylinder which compresses per second a weight of air w, when the time, T, required per single stroke of the compressor (or per double stroke when the compressor is single-acting), is given in seconds.

2. The final temperature of the compressed air. This is found by looking in Table I. for the values of $\frac{\tau}{\tau_0}$ opposite the different values of $\frac{p}{p_0}$. Supposing the initial temperature $\tau_0 = 293° = 20°$C., we find for the different values of $\frac{p}{p_0}$ the values of τ_1 in degrees of absolute temperature and degrees C., as follows :

TABLE II.

$\frac{p_1}{p_0}$	τ_1	Final Temperature in Degrees C.
2	358.2	85.2
3	402.9	129.9
4	437.9	164.9
5	467.2	194.2
6	492.6	219.6
7	515.1	242.1
8	535 4	262.4
9	554.1	281.1
10	571.3	298.3
11	587.2	314.2
12	602.2	329.2
13	616.4	343.4
14	629.8	356.8
15	642.5	369.5

V.

THE THEORY OF TRANSMISSION.

1. *Loss of Pressure due to Transmission.*—The loss in pressure which results from carrying compressed air from one point to another point distant from the first, is due,

1.° To the friction between the air and the conveying pipes;

2.° To sudden contractions in the pipes;

3.° To sharp turns and elbows.

From experiments made at the Mont Cenis Tunnel, the loss of pressure from friction in pipes was formulated thus:—

$$\Delta p = .00936\frac{u^2 l}{d}, \quad (37)$$

where u=the velocity of the air per second,

l=length of the pipes,

d=diameter " "

Hence the loss of pressure varies, directly as the length of pipe; directly as the square of the velocity of the air in the pipe; inversely as the diameter of the pipe.

If w be the weight of air required by the working-cylinder per second, $3.1416\frac{d^2}{4}u$ being the volume of air passing through the pipe per second, and p_1 and τ_1 being the pressure and absolute temperature respectively of the air in the reservoir, we have, from eq. (34*a*)

$$\frac{3.1416\frac{d^2}{4}up}{\tau_1}=Jw(c-c');$$

Solving with respect to u and substituting in (37), we have,

$$\triangle p=13.88\frac{w^2\tau_1{}^2 l}{p_1{}^2 d^5}$$

when Joule's equivalent is taken in French units; when taken in British units (772 foot-pounds per British thermal unit), we have,

$$\triangle p=43.055\frac{\tau_1{}^2 w^2}{d^5 p^2}l \qquad (38)$$

which expresses the loss of pressure due to friction in the pipes as a function of the weight of air supplied per second, of the temperature and pressure of the air in the reservoir, and of the length and diameter of the pipe.

2. *Difference of Level.*—The difference of level which exists between the reservoir and the compressor and the compressed-air engine (as when the latter is at the bottom of a mine) compensates in part at least for the loss of pressure due to the friction in the supply-pipes. The gain in pressure due to this difference of level is readily calculated by means of the ordinary barometric formulae. (See Wood's Elementary Mechanics, p. 327).

VI.

THE THEORY OF COMPLETE-EXPANSIVE WORKING.

1. *Notation.*—Let θ_0=the absolute temperature of the compressed air when it enters the working cylinder;

θ_1=the absolute temperature of the air after expansion;

ψ_0=the pressure of the compressed air on entering the working-cylinder;

ψ_1=the pressure at the end of expansion.

2. *Work theoretically obtainable.*—This is given in Chap. IV, Section III, and is:

$$W_2=Jwc(\theta_0-\theta_1)=Jwc\vartheta_0\left\{1-\frac{\theta_1}{\theta_0}\right\}$$

$$=Jwc\theta_0\left\{1-\left(\frac{\psi_1}{\psi_0}\right)^{\frac{r-1}{r}}\right\}, \qquad (39)$$

$\frac{\theta_1}{\theta_0}$ being obtained from the formula for the

3. *Final Temperature.*—This is given by eq. ($34d$) and is:

$$\frac{\theta_1}{\theta_0}=\left\{\frac{\psi_1}{\psi_0}\right\}^{\frac{r-1}{r}}$$

it can be calculated directly by the use of Table I when we know $\frac{\psi_1}{\psi_0}$, the ratio of the final to the initial temperature.

4. *Volume of the Working-Cylinder.*—The volume of the working-cylinder, being the same as the final volume of the air after expansion is, from eq. ($34a$),

$$V_2=Jw\frac{\theta_1}{\psi_1}(c-c')\,T \qquad (40.)$$

where w=the weight of air furnished per second and T=the time in seconds of one stroke.

5. *Weight of Air required per Second.* This is determined by the work which is to be done by the compressed-air engine per second. Letting n be a certain coefficient embracing resistances of all kinds, we have, Chap. IV, Section III.

$$w=\frac{W_2}{k\,Jc(\theta_0-\theta_1)} \qquad (41)$$

Substituting this value of w in eq. (36) we have,

$$V_1=\frac{R}{Jc}\times\frac{W_2T}{k\,(\theta_0-\theta_1)}\times\frac{\tau_0}{p_0}=\frac{r-1}{r}\times\frac{W_2T}{k\,(\theta_0-\theta_1)}\times\frac{\tau_0}{p_0}, \qquad (42)$$

the volume of the compressor in order to supply the given amount of air.

6. *Cold resulting from Expansion.*—While in the compressor there is a great development of heat from the compression of air, in the working-cylinder there is a great fall of temperature due to its expansion. The final temperature θ_1 is calculated from the formula of Chap. IV, Sec. VI, 3.

The valves of $\frac{\theta_1}{\theta_0}$, corresponding to $\frac{\psi_1}{\psi_0}$, and the reciprocals, are found from Table I. The following table is from M. Mallard. The initial absolute temperature is assumed $\theta_0=293°$, that is, 20° C.

This table shows what very low temperatures are reached when we work full expansion with air at a high pressure. Ice is formed from the water-vapor present in the air, and seriously interferes with the action of the working engine.

TABLE III.

$\frac{\psi_1}{\psi_0}$	Final Temperature.	
	Absolute θ_1.	Degrees C.
2	239.6	— 33.4
3	213.0	— 60.0
4	196.0	— 77.0
5	183.7	— 89.3
6	174.2	— 98.8
7	166.6	—106.4
8	160.3	—112.7
9	154.9	—118.1
10	150.1	—122.9
11	146.1	—126.9
12	142.5	—130.5
13	139.2	—133.8
14	136.3	—136.7
15	133.6	—139.4

VII.

THE THEORY OF FULL PRESSURE WORKING.

1. *Work obtainable.*—This is, in the present case, expressed by the equation,

$$W_2 = V_2(\psi_0 - \psi_1). \tag{43}$$

Placing in this equation the value of V_2 from eq. (40) we have,

$$W_2 = Jw(c-c')\theta_0\left\{1-\frac{\psi_1}{\psi_0}\right\}. \tag{44}$$

The general expression for the work restored has been given by eq. (39), where θ_1 is the temperature of the air after it has been exhausted and has assumed the pressure of the atmosphere ψ_1.

2. *Final Temperatnre.*—Placing eqs. (44) and (39) equal to each other,

$$\frac{c-c'}{c}\left(1-\frac{\psi_1}{\psi_0}\right)=\left(1-\frac{\theta_1}{\theta_0}\right)$$

or, $$\frac{\theta_1}{\theta_0}=\frac{1}{r}+\frac{r-1}{r}\,\frac{\psi_1}{\psi_0}=.7102+.29\frac{\psi_1}{\psi_0} \tag{45}$$

3. *Weight of Air necessary per Second.*—This is given by eq. (41).

4. *Volume of Cylinder.*—Substituting w, eq. (41), in eq. (34a), we have,

$$V_1=\frac{c-c'}{c}\times\frac{W_2\,T}{\psi_0\left\{1-\frac{\theta_1}{\theta_0}\right\}k} \tag{46.}$$

VIII.

THEORY OF INCOMPLETE EXPANSIVE WORKING.

1. *Work attainable.*—This is given by eq. (39).

2. *Final Temperature.*—We have, eq. (34a),

$$\frac{\theta'_1}{\theta^0}=\left\{\frac{\psi'_1}{\psi_0}\right\}^{\frac{r-1}{r}},$$

from which we get θ'_1 (the temperature at the end of the stroke). θ_1 is then found from the equation,

$$\frac{\theta_1}{\theta'_1}=\frac{1}{r}+\frac{r-1}{r}+\frac{\psi_1}{\psi_0}.$$

3. *The weight of air used.*—This is given by eq. (41.)

4. *Volume of the Cylinder.*—Eq. (34a), written to satisfy our conditions, becomes:

$$V_1=J(c-c')wT\frac{\theta'_1}{\psi'_1},$$

or, substituting the value of w from eq. (41),

$$V_1=\frac{r-1}{r}\,\frac{W_2T}{\psi'_1\frac{\theta_0}{\theta'_1}\left\{1-\frac{\theta_1}{\theta_0}\right\}}. \tag{47}$$

IX.

GRAPHICAL REPRESENTATION FOR THE ACTION OF COMPRESSED AIR.

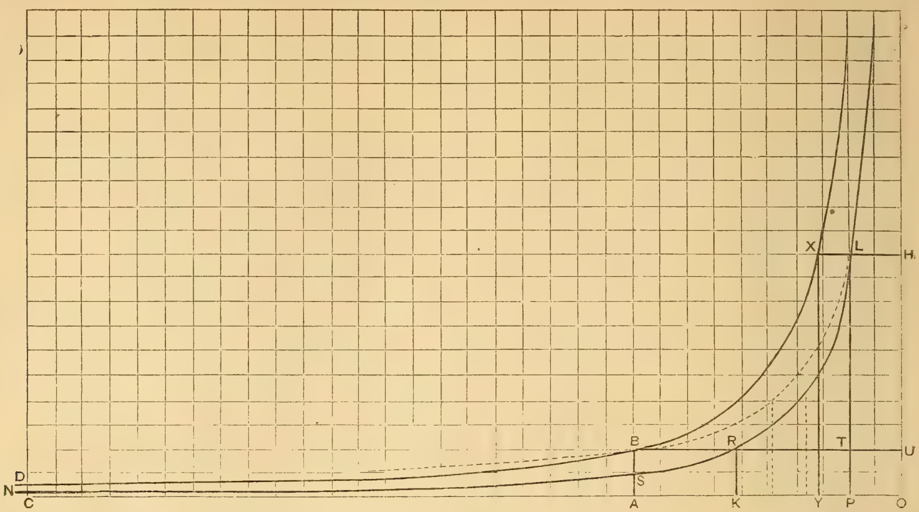
Let abscissas, in diagram on next page, be volumes and ordinates, pressures; taking O for the origin. Through B (p_0v_0) construct an adiabatic curve from its equation, (eq. 27).

"The *intrinsic energy* of a fluid is the energy which it is capable of exerting against a piston in changing from a given state as to temperature and volume, to a total privation of heat and indefinite expansion." The intrinsic of 1 lb. of air at p_0 and v_0, will be represented by the area included between the axis of abscissas, the ordinate AB$=p_0$ (at a distance from the origin OA$=v_0$), and the portion of the adiabatic curve extending indefinitely from B until it becomes tangent to the axis of abscissas when $x=\infty$. The algebraic expression for this area (found by integrating eq. (27 a) between the limits ∞ and v_0 is,

$$I=\frac{p_0v_0}{r-1}. \tag{47A}$$

p_0=mean pressure of atmosphere in lbs. per square foot=2116.3;

v_0=volume in cubic feet of 1 lb. of air at pressure p_0 and temperature τ_0 =12.387;



$\tau_0 = 493.°2$ corresponding to 32° F;
$r = 1.408$; hence

$$I = \frac{p_0 v_0}{r-1} = 64250 \text{ foot-pounds;}$$

that is, one pound of air, at mean barometer pressure and 32°F, possesses an intrinsic energy of 64250 foot-pounds; and *it is upon this store of energy that we draw, when, after abstracting in the form of heat all the work we had expended in compressing the air, we yet cause it to perform work by expansion.*

Through B construct an isothermal curve from its equation (eq. 1). At a point (as L) chosen arbitrarily upon this curve to correspond to a desired pressure we can construct another adiabatic curve LRN. Then will the relations exist, expressed in the following, as given by Prof. Frazier :

Area ABDC prolonged indefinitely= intrinsic energy possessed by the air before compression=I.

Area ABLPA=the work performed in compressing the air.

Area DBLRN prolonged indefinitely= ABLPA=energy in the form of heat abstracted by the cooling water; consequently, BSND prolonged indefinitely=ASLPA.

Area CKRN prolonged indefinitely= intrinsic energy of the air after expansion.

Area KRLPK=work performed by the air in its expansion.

Area ABRKA=work performed by the air after it leaves the working-cylinder.

Area DBRSN prolonged indefinitely= ABRLPA=the heat absorbed by the air after leaving the working-cylinder. For isothermal compression, we have,

Area ABLHOA=total work performed in the compressing-cylinder.

Area ABLPA=work performed in the compression of the air.

Area PLHOP=work performed in the expulsion of the air from the compressor.

Area ABUOA=work performed by the atmosphere.

Area UBLHU=ABLPA=the work performed by the motor.

Area UTLHU=useful work performed by the air (full pressure).

Area UBLHU − UTLHU = TLBT= amount of work lost.

For adiabatic compression we have :

Area ABXYA=work performed in the compression of the air.

Area YXHOY=work performed in the expulsion of the air from the compressor.

Area ABUOA=work performed by the atmosphere.

Area BXHUB=work performed by the motor.

Area TLHUT=useful work performed by the air (full pressure).

Area BXLTB=BXHUB−TLHUT= amount of work lost.

When the air is allowed to expand fully (to its original pressure p_0),

Area RTLR=useful work of expansion.

Area UHLRU=total useful work (= UTLHU+RTLR).

Area BXLRB= BXHUB− UHLRU =amount of work lost where air is cooled after leaving the compressor.

Area BLRB = UBLHU−UHLRU= amount of work lost where air is cooled completely in compressor.

The area BLRB represents, then, the excess of work performed on the air above that performed by it, or the amount of work permanently transformed into heat. It is, therefore, not possible, even by preventing any rise of temperature during compression and allowing the air to expand to its full extent, to obtain from the compressed air as much work as was expended in the compression. We can obtain from compressed air all the work expended upon it, only by causing it to reproduce exactly during its expansion the changes of condition it underwent during compression. This may theoretically be accomplished in three ways.

1. By allowing the compressed air to become heated during compression, and preventing all transmission of heat until it leaves the working cylinder. It will be compressed and expand in this case, following the curve BX.

2. By cooling the air during compression and heating it during its expansion, in such a manner that its temperature, shall remain constant during both operations. The air will be compressed and expand in this case, following the curve BL. The heat abstracted during compression will equal that supplied during expansion.

3. By cooling the air *before* its compression to such a degree that after it is compressed it will have the temperature of the media surrounding the working cylinder. The air will be compressed and expand in this case, following the curve RL.

CHAPTER VI.

Efficiency Theoretically Attainable.

I.

EFFICIENCY OF THE AIR-COMPRESSOR AND COMPRESSED-AIR ENGINE, AS A SYSTEM.

$$\frac{\text{Work performed on the air}}{\text{Work performed by the air}} = \text{the efficiency} = \mathrm{E};$$

hence,

$$\mathrm{E}=\frac{\mathrm{W}_2}{\mathrm{W}_1}=\frac{Jc(\theta_0-\theta_1)w}{Jc(\tau_1-\tau_0)w}=\frac{\theta_0\left\{\dfrac{\theta_0}{\theta_1}-1\right\}}{\tau_1\left\{\dfrac{\tau_1}{\tau_0}-1\right\}}$$

$$=\frac{\theta_1}{\tau_0}\times\frac{\left\{\dfrac{\psi_0}{\psi_1}\right\}^{\frac{r-1}{r}}-1}{\left\{\dfrac{p_1}{p_0}\right\}^{\frac{r-1}{r}}-1} \qquad (48.)$$

In practice, $\dfrac{\psi_0}{\psi_1}$ and $\dfrac{p_0}{p_1}$ differ very little in value, their difference being due to the loss of pressure from the friction between the air and the supply-pipe, a loss which is very small if the pipes are of sufficient diameter.

Hence we may write,

$$\mathrm{E}=\frac{\theta_1}{\tau_0}, \qquad (48a)$$

that is to say, when compressed air is made to expand completely, and when the ratio of its pressure to the pressure of the surrounding atmosphere is the same when the air leaves the compressor as when it enters the cylinder of the compressed-air engine, the efficiency of the system is the ratio of the temperature of the compressed air when it leaves the compressed-air-engine cylinder to the temperature of the air at its entrance into the compressor.

This law is independent of any heat lost by the air in passing from one cylinder to the other.

Since we have just admitted that,

$$\frac{\psi_1}{\psi_0}=\frac{p_0}{p_1}$$

we have,

$$\frac{\theta_1}{\theta_0}=\left\{\frac{\psi_1}{\psi_0}\right\}^{\frac{r-1}{r}}=\left\{\frac{p_0}{p_1}\right\}^{\frac{r-1}{r}}=\frac{\tau_0}{\tau_1};$$

hence,

$$E=\frac{W_2}{W_1}=\frac{\theta_1}{\tau_0}=\frac{\theta_0}{\tau_1}, \qquad (48b)$$

showing that the loss of work is proportional to the loss of heat undergone by the compressed air in its passage from the compressor to the working-cylinder.

The efficiency will be a maximum when $\tau_1=\theta_0$; that is, when the loss of heat is nothing. Of course, this condition cannot be realized. Generally the compressed air reaches the working cylinder with a temperature equal to that of the surrounding atmosphere. The temperature θ_0 is therefore given, and the efficiency can only be increased by diminishing τ_1.

The following table is calculated from (eq. 486) for different values of $\frac{p_1}{p_0}$ the temperature of the compressed air at entering the working cylinder being taken $\theta_0=293°$, that is, 20° C.

TABLE IV.

$\frac{p_1}{p_0}$	E.	$\frac{p_1}{p_0}$	E.
2	.82	9	.53
3	.72	10	.51
4	.67	11	.50
5	.63	12	.49
6	.60	13	.48
7	.57	14	.47
8	.55	15	.46

The table shows that when the pressure has reached four atmospheres, even a considerable increase of it does not much effect the efficiency.

II.

MAXIMUM EFFICIENCY CALCULATED FROM THE INDICATED WORK.

Let P=the pressure of the compressed air,

Let p=the pressure of the atmosphere,

Y and v=the corresponding volumes; also let $P=np$; then $V=nv$.

The work spent upon the air to compress it, is, (eq. 26),

$$W_1=pV \text{ nap. log. } \frac{V}{v}=pV\times 2.303 \text{ com. log. } n$$

The work performed by the air is :

$$W_2=(P-p)v,$$

and as $Pv=pV$, and $V=nv$, we have

$$W_2=pV\left\{1-\frac{1}{n}\right\};$$

hence,

$$E=\frac{W_2}{W_1}=\frac{pV\left\{1-\frac{1}{n}\right\}}{pV\times 2.303 \text{ com. log. } n}=\frac{\left\{1-\frac{1}{n}\right\}}{2.303 \text{ com. log. } n} \qquad (49.)$$

Substituting different values of n in this formula we get the corresponding values of E.

III.

THE EFFICIENCY OF COMPLETE EXPANSION AND OF FULL PRESSURE COMPARED.

To show the comparative merits and demerits of full pressure and complete expansion in the use of compressed air, we present a table prepared by M. Mallard.

(*See Table on following page.*)

The initial temperature is assumed at 20°C.

The table shows that by working non-expansively we avoid very low temperatures of exhaust; but this is of little practical importance when we take into account the low efficiency of full pressure, as compared with complete expansive working. Also when working at full pressure, the higher the working pressure the lower the efficiency.

CHAPTER VII.

THE EFFECTS OF MOISTURE, OF THE INJECTION OF WATER, AND OF THE CONDUCTION OF HEAT.

I.

GENERAL STATEMENTS.

In dealing with compressed air we must always keep in view the very important consideration of the *initial* and *final temperature* of the air.

There are two principal causes tending to vary the amount of heat present in the compressor or absorbed in the working-cylinder:—

1. The water or water-vapor of which atmospheric air always contains more or less, and which is purposely introduced

TABLE V.

$\frac{p_0}{p_1}$	Final temperature. Degrees C. Complete expansion.	Theoretical efficiency with complete expansion.	Final temperature. Degrees C. Full pressure.	Theoretical efficiency with full pressure.	Ratio of efficiency at full pressure to efficiency at complete expansion.
2	— 33.4	.855	—22.4	.82	.95
3	— 60.0	.806	—36.9	.72	.90
4	— 77.0	.782	—43.2	.67	.86
5	— 89.0	.768	—48.0	.63	.82
6	— 98.0	.758	—51.0	.60	.79
7	—106.0	.751	—53.0	.57	.74
8	—112.7	.746	—54.5	.55	.73
9	—118.1	.742	—55.6	.53	.71
10	—122.9	.739	—56.5	.51	.69
11	—126.9	.736	—57.4	.50	.68
12	—130.5	.734	—58.0	.49	.66
13	—133.8	.732	—58.6	.48	.65
14	—136.7	.730	—59.2	.47	.64
15	—139.4	.729	—59.5	.46	.63

into the cylinder of the so-called wet-compressors.

2. The conduction of heat by the cylinders, supply-pipes, reservoirs, &c.

II.

THE EFFECTS OF MOISTURE.

Atmospheric air always contains more or less moisture. We wish to consider the effects of this moisture upon the air undergoing compression or expansion. The injection of water into the cylinders and its cooling or heating effects are left out of the question altogether, as they will receive attention further on.

In all conditions of temperature and pressure practically realizable, a mixture of air and saturated water-vapor will remain saturated when the mixture expands against a resistance, a certain quantity of water being thereby condensed; on the contrary, compression superheats the vapor, which then becomes non-saturated, and non-saturated vapors follow the laws of permanent gases.

1. *Influence of water-vapor upon the work spent on the air and upon that performed by it.*—The presence of moisture in the air has been found to be favorable both in the compressor-cylinder and working-cylinder. In both cases, however, the gain in work spent or performed is so slight that it can be entirely neglected, and the formulas already established for dry air become applicable with a sufficiently close approximation. In the case of compression, the vapor is superheated and therefore comports itself very much like the air itself; while in the working-cylinder, the increase of work performed, when the initial temperature of the compressed air does not exceed 30° C., is very small; and, as the temperature at which compressed air is used, is rarely higher than 20° C., the influence of the water-vapor can be safely neglected.

2. *Influence of the moisture of the air upon the Final Temperature.*—The presence of the moisture in the atmospheric air introduced into the compressor tends to lessen the heat of compression; this effect, however, is very slight, and, in a practical point of view, is not worth considering.

When compressed air is completely expanded in a working-cylinder, the presence of moisture in it tends to lessen the cold produced. M. Mallard has found what the initial pressure would be for certain initial temperatures, so that the final temperature should not fall below 0° C. He has found this for both dry and saturated air, and his results are tabulated as follows:—

(*See Table on following page.*)

This table shows that, if compressed air at 50°C and at a pressure of three atmospheres be introduced into a working-cylinder, this air, if saturated with aqueous vapor, can be completely expanded without falling to a temperature below 0°C; and that this air, if dry, dare

Table VI.

Final temperature. Degrees C.	Initial temperature. Degrees C.	Value of $\frac{\psi_0}{\psi_1}$ with the air.	
		Saturated with water-vapor.	Dry.
0°	20°	1.50	1.276
0°	30°	1.89	1.432
0°	40°	2.39	1.602
0°	50°	3.06	1.780

not exceed an initial pressure of 1.78 atmospheres if its final temperature is not to fall below 0°C.

3. *Volume of the Cylinders.*—This is calculated as for dry air, since the effect of the moisture is too slight to be taken into account.

III.

THE INJECTION OF WATER.

1. *The Effect of Introducing Water into the Compressor-Cylinder.*—It is of great advantage in practice to introduce cold water into the compressor. It carries away the heat of compression to a very great extent. It acts as a lubricant, and, by cooling the cylinder, it prevents the destruction of any organic material, such as packing, valves, &c., that may be employed upon it.

If in addition to the atmospheric moisture present in the air at its entrance into the compressor, water be introduced in quantities just sufficient to keep the air saturated with water-vapor during the compression, the work spent upon the air and the final temperature at the end of compression will both be less than if the air had not been kept saturated while being compressed. It is unnecessary to calculate the amount of work saved or the extent of temperature reduced by the presence of this saturated water-vapor; for if water is at all to be introduced into the compressor, it may as well be thrown in in larger quantities, that is, in quantities sufficient to absorb and to carry off the greater part of the heat of compression.

The effects of the heated air in the compressor is a great cause of loss of motive power, and it is very desirable to cool the air during its compression.

The final temperatures for different pressures have already been given in Table II. We repeat them here in connection with the quantities of work spent when the compression follows Boyle's law and when it is effected without any removal of heat.

Table VII.

Tension in atmospheres.	Compression with temperature constant.		Compression with increase of temperature.			Loss of work due to the heat of compression. kilogram-meters.	Fraction of the total work required for compression, which is converted into heat.
	Volume in cubic meters.	Work in kilogram-meters.	Temperature in Degrees C.	Volume in cubic meters.	Work in kilogram-meters.		
1	1.00		20°	1.			
2	.50	7,199	85°.5	.612	7,932	733	.092
3	.333	11,356	130°.4	.459	13,360	2004	.150
4	.250	14,260	165°.6	.374	17,737	3477	.196
5	.200	16,580	195°.3	.320	21,209	4629	.213
6	.167	18,475	220°.5	.281	24,310	5835	.240
7	.143	20,038	243°.2	.252	27,048	7040	.260
8	.125	21,422	263°.6	.229	29,518	8096	.274

The Quantity of Water to be Injected.—We have found eq. (26), that the quantity of heat developed by compression is given by the formula,

$$Q=\frac{R\tau_0}{J}\text{ nap. log.}\left\{\frac{v_0}{v_1}\right\},$$

where τ_0 is the absolute final temperature $=273°+40°=313°$. From this formula the quantity of heat, Q, is calculated for different pressures. We then find the weight of water, which, if introduced at 20°C and removed when it has taken up enough heat to raise its temperature to 40°C, would absorb this quantity of heat Q. Under these conditions we find that

each kilogramme of water will absorb 20 calorics. Dividing Q by 20 we get the weight of water to be introduced in kilogrammes. In this way the following table was prepared:

TABLE VIII.

Absolute pressure to which the air is compressed.	Heat developed by compression and to be carried off by the injected water.	Weight of water at 20° C. to be injected into the compressor per kilogramme of air compressed in order to keep the final temperature from rising above 40° C.
atmospheres.	calories.	kilogrammes.
2	14.695	.734
3	23.284	1.164
4	29.392	1.469
5	34.120	1.701
6	37.979	1 891
7	41.264	2.063
8	44.087	2.204
9	46.589	2.329
10	48.816	2.440
11	50.849	2.542
12	52.694	2.634
13	54.391	2.719
14	55.962	2.798
15	57.425	2.871

2. *The Injection of Hot Water into the Cylinder of the Compressed-Air Engine.*—In the production of compressed air, the great cause of loss of motive power, as we have seen, is the development of heat. Analogous to this is the loss which occurs in the *use* of compressed air. Great cold is produced by expansive working, and this has long forbidden its adoption. The injection of hot water into the working-cylinder, has now made it possible to attain the desirable result of working expansively.

The Quantity of Hot Water to be Introduced.—The quantity of heat, Q, to be supplied to keep the temperature of the expanding air constant is found from eq.(26), to be,

$$Q=\frac{R\tau_0}{J} \text{ nap. log.}\left\{\frac{v_1}{v_0}\right\}.$$

The expansion being supposed to follow Boyle's law, we have,

$$p_1v_1=p_0v_0, \text{ or } \frac{v_1}{v_0}=\frac{p_0}{p_1}$$

Hence we have,

$$Q=\frac{R\tau_0}{J} \text{ nap. log.}\left\{\frac{p_0}{p_1}\right\}.$$

$p_1=1$ in this case since the air is expanded down to atmospheric pressure. From this formula the weight of water to be injected is calculated as in table. The results are given in the following:

TABLE IX.

Absolute pressure at which the compressed air is introduced into the working cylinder.	Quantity of heat to be supplied to keep the temperature of the air from falling below 0° C. during its expansion down to atmospheric pressure.	Weight of water to be injected into the working cylinder per kilogramme of compressed air introduced to keep the final temperature from falling below 0° C. The temperature of the water introduced being		
		20° C.	50° C.	100° C.
2	13.280	.134	.103	.074
3	21.030	.212	.163	.117
4	26.550	.262	.206	.148
5	30.828	.311	.240	.178
6	34.334	.346	.266	.192
7	37.285	.376	.289	.208
8	39.833	.402	.309	.223
9	42.094	.425	.326	.235
10	44.106	.445	.342	.247
11	45.945	.464	.356	.256
12	47.612	.480	.369	.266
13	49.145	.496	.381	.274
14	50.562	.510	.392	.282
15	51.885	.524	.402	.290

The quantities of water here given are the minima values since the latent heat which is released by the water in freezing has not been taken into account. Hence

to avoid the formation of ice we must add a slight excess of hot water.

3. *The Effect of the Conduction of Heat by the Cylinders, Pipes, &c.*—Since the temperature of the compressed air when used is most always that of the surrounding atmosphere, the result of the conduction of heat by the containing vessels is the dissipation of the total heat of compression. The mechanical equivalent of this heat is, of course, lost work, and, as it is most economical to get rid of this heat during compression, conduction and radiation from the compressor is an advantage. Since, in working expansively, there is a tendency for the cylinder to become colder than surrounding bodies, the conduction and radiation of heat is here too, if anything, an advantage.

In all our formulas and results hitherto established, the cylinders have been supposed non-conducting; and the investigations of M. Mallard have shown that this hypothesis is justified. For the heat leaving the compressor by conduction and radiation is in part compensated for by that developed by the friction of the piston; and the heat conducted through the working cylinder is very small relatively to that converted into work. Hence, any passage of heat by conduction of the cylinders belongs to those secondary quantities which are always omitted in the general theory of motors, except so far as allowed for by proper coefficients.

CHAPTER VIII.

American and European Air-Compressors.

I.

PUMP COMPRESSORS.

Pump or plunger compressors are generally in high repute in Germany and Austria, especially in mines, and they seem to give very satisfactory results. In the United States they never have been used to any considerable extent and are now not at all used.

It must be said to the prejudice of these compressors, that, in consequence of the large mass of water to be pushed back and forth by the plunger, a large per-cent. of power is wasted in overcoming inertia; that high piston speeds are, in consequence of the violent shocks which result, utterly impossible; that they are very heavy and hence require expensive foundations; that when the prime mover is run at a high speed, a more or less cumbrous, expensive, and wasteful machinery of transmission is necessary; that their use is limited, pressures of 5 or 6 atmospheres being their utmost capability, on account of the large quantity of cooling water taken up by the air at even moderately high tensions; that a large amount of cooling-water is required to produce a comparatively small effect in the abstraction of heat.

On the other hand, it must be admitted that these compressors are liable to very few repairs, that they are simple in construction and that "dead spaces" are avoided.

The hydraulic or ram compressors first used by Lommeiller at the Mt. Cenis Tunnel have become obsolete.

II.

SINGLE-ACTING WET COMPRESSORS.

The air compressors now used in the United States are either "*Dry Compressors*" in which the cooling is effected by flooding the external of the cylinder, and sometimes also the piston-rod aid-head, with water; "*Wet Compressors*," by the injection of water into the cylinder-space, as well as by external flooding; *compressors* with *no* cooling arrangement are seldom used, and only in temporary and cheap plants.

Compressors with a partial injection of water have been used to very good effect in the United States. Most of these are single-acting, and are represented by the machines of Burleigh, of Fitchburgh, Mass. The cooling is very efficient and hence the useful effect is considerably increased. They are very durable and not liable to get out of repair, as is shown by the record of Burleigh's machines which have stood the test of years of steady work.

The use of single-acting compressors renders it necessary that, in all cases where anything like a uniform supply of air is needed, to have two compressor-cylinders. These cannot be driven directly from the piston-rod of the driving engine, but necessitate an indirectly coupled-connection of some sort.

All this makes single-acting compressors somewhat cumbrous and expensive.

As built to-day, the evils of dead spaces, and of jars and shocks resulting from water in the cylinder, have not been duly considered. There are also a few cases when the sectional area of the inlet-valves is insufficient; and in general those parts which are most liable to get out of repair are most difficult of access.

We are inclined to think that the claim of the Burleigh Co., that their compressor is the most efficient, economical, and durable of any built in this country, cannot be far from the truth.

III.

DOUBLE AND DIRECT-ACTING COMPRESSORS.

Up to within several years ago, single-acting compressors have been used almost exclusively. Now the double and direct-acting compressor seems to be superseding it. This is now the leading type of American compressor, although hitherto it has given at least no better results than the best single-acting machine.

Superiority in the double-acting compressor is found in its simplicity. The piston of the engine drives the compressor by a direct connection. All wasteful and cumbrous machinery of transmission is at once unnecessary and high piston-speeds are possible; in the United States from five to seven feet.

Most American double and direct-acting compressors are of the dry kind. These have the advantage that the air is delivered without having any water mechanically mixed with it. Hence very much ice cannot be formed when the air is worked expansively. Higher rates of expansion are possible than with air from a wet compressor.

One of the very best American double and direct-acting dry compressors is the "National," built by Allison & Brannan, Port Carbon, Pa., (Office, 95 Liberty St., N. Y.). Steam cylinders of the medium sized duplex machine are $12'' \times 42''$, and the air cylinders $15'' \times 42''$. The air pistons work to within one sixteenth of an inch of the cylinder heads. The water circulation for cooling passes spirally around the air cylinder from the center to each end. The engine will compress air to the same pressure as that of the steam used. The amount of free air compressed at a piston speed of 350 feet is about 1000 cubic feet per minute. A greater pressure of air than the pressure of steam used is obtained by increasing the size of the steam cylinder, or decreasing that of the air cylinder.

The best double and direct acting compressor of the wet kind is undoubtedly that of Dubois Francois, built in Seraing, Belgium, and exhibited at the Centennial Exposition, in 1876.

Dry compressors, although the cheapest as regards first cost, are not the most economical in working. But where air is to be carried through pipes exposed to great cold they are the only alternative.

IV.

DESIGN AND CONSTRUCTION.

The efforts of builders and engineers should be directed to the attaining of a higher efficiency, and they should not, as is now often the case, sacrifice the latter to cheapness and small dimensions. To attain such desirable efficiency the heat of compression must be more effectually abstracted. This must be done by a more ingenious and rapid circulation of water around the cylinder, and injection of water in the form of spray into the cylinder. But the injection of water in some efficient and practical manner, which is so essential to the reaching the highest efficiency, introduces the great disadvantage of having to work with wet air. Hence we see how important would be an invention of means or apparatus for separating the water from the air when direct intercontact has been had to keep down the temperature. We must also remember the important physical fact that water absorbs very considerable volumes of air—volumes dependent upon the pressure of the air and the amount of surface of water exposed to the fluid contact, time being also an important factor.

Clearance must be reduced to the smallest possible amount. It has been brought down in a few cases to 0.39 inch. A long stroke, one from 2 to to 3 times the diameter of the cylinder, is another means of avoiding loss from dead spaces, since here the air which fills the dead space is small in comparison with that actually delivered. The

valves must be so placed that, between their seats and the piston-head at the end of the stroke there shall be the smallest possible clearance.

The valves themselves, to close the more rapidly, are made to have only a very small travel. (This has been made as small as .08 to .12 inch.) The valve-area must be made large enough by increasing the number of the valves. The valve-area should be amply large, generally from $\frac{1}{5}$ to $\frac{1}{10}$ of the sectional area of the cylinder. The valves should be so attached to the cylinder head that they may be removed and repaired without taking off the latter or otherwise taking the machine apart.

Great care must be taken to have the piston head fit the cylinder accurately and closely, since, especially in dry compressors, great losses result from any looseness. The piston-heads should be made so that they can be adjusted to preserve a nice fit, as in steam engine practice. Lubrication of the cylinder in case of the dry compressor should be effected by automatic oil cups placed upon it.

It must also be borne in mind that the working pressure is that which most influences the physical conditions of working, and the suitable mode of construction. And, although the loss of work increases with the pressure, yet the *rate of variation* of the loss of work decreases as the pressure increases. As great a proportion of work is lost by increasing the pressure from two to three atmospheres as by increasing it from five to ten atmospheres.

The tendency in Germany and France, as well as here, is for the wet compressor entirely to supersede all others. But it is scarcely too much to say that the air-compressor of the future has yet to be invented.

CHAPTER IX.

Examples from Practice.

I.

The Republic Iron Company of Marquette, Mich., have done away with the use of steam, by utilizing the power of a water-fall situated about a mile from their works. The power is transmitted by means of compressed air which drives all their machinery, and thus saves the cost of fuel.

There are four compressors, 24″ diameter and 5′ stroke, driven by two turbine Swain water-wheels $5\frac{1}{2}'$ diameter, under 16 feet head of water. As near as has been ascertained, they have about 450 horse power at the wheels. The air is carried one mile in a pipe built of boiler iron, 15″ inside diameter. About 66 per cent. of the effective power of the wheels is obtained at the mines and shops.

II.

ECONOMY PROMOTED BY THE USE OF COMPRESSED AIR.

To show the great saving of both time and money since the introduction of compressed-air machinery we will give a few figures.

It cost the Golden Star Mining Co., of Sacramento \$12 to \$15 per foot to run a tunnel 7×7 feet when employing hand labor; after introducing air machinery it cost them \$6 to \$7 per foot; with hand labor they made a distance of two feet per day; with machine labor, a distance of six feet per day.

Another instance, among many, is that of the Sutro Tunnel Company of Nevada;

Expense by hand labor per month..................\$34,000 to \$50,000.
Expense by machine labor per month...............\$14,000 to \$16,000

III.

COMPRESSED-AIR MOTOR STREET CAR.

The pneumatic engine which has been on trial by the Second Avenue Railroad Company, on the Harlem portion of their road, from the Station at Ninety-Sixth Street, to Harlem River, at One-Hundred-and-Thirtieth Street, has proved so satisfactory to the company that it has authorized the construction of five more engines.

These are to be used exclusively on the upper part of the road, where it is proposed to dispense entirely with the use of horse power, so soon as the requisite number of engines shall be procured. It was stated at the company's office yesterday that the most sanguine expectations had been fulfilled; the new engine could be run at a trifling cost, and without the noise and smoke and

smell of oil which accompany the use of steam; any rate of speed which was likely to be required could be maintained, and the engine was under as complete control of the engineer as one propelled by steam or a car drawn by horses. It was not known whether any change was proposed below the station at Ninety-Sixth Street; certainly none at present.

The new engines are manufactured by the Pneumatic Tramway Engine Company, whose office is at No. 317 Broadway. Some time ago two Scotch engineers, Robert Hardie and J. James, invented a system of propelling cars by means of compressed air. The invention was examined by a number of practical railroad men who were visiting Scotland. Hardie and James were induced to visit this country and the company was organized. Experiments have been making for a year, resulting in improvements which now seem likely to render the invention serviceable to the public. The motive power is condensed air, contained in two reservoirs, placed one under each end of a car, which is similar in construction to those in ordinary use on street railways. The air is pumped in by a stationary engine at one hundred and twenty-seventh street, and this has been so far improved that the reservoirs in the cars now used are filled in a few minutes. These are of steel, and are tested up to a strength many times greater than their working pressure, and it is claimed that there is no danger of explosion. The machinery is simple and not liable to get out of order. The air-tanks of the experimental car are only sufficiently large to enable it to make one round trip between Harlem and Ninety-Sixth Street stations; but the cars now building will be larger and will contain reservoirs of much greater capacity; and it is claimed that there will be no difficulty in constructing them so that the round trip from Harlem river to Peck Slip can be made without replenishing.

Mr. Henry Bushnell, of New Haven, is the inventor and constructor of a new compressed air motor street car, the chief peculiarity of which is that he is able to force air into his receivers until his gauge registers the enormous pressure of more than 3,000 pounds per square inch. His receivers are tubes, the largest of which are twenty feet long, and only eight inches in diameter, inside measurement. There are four of these, two lying side by side above the axles, and next to the wheels on either side of the car. Between them at one end are four other tubes, each six feet long and six inches in diameter, inside measurement. The material is wrought iron three-eighths of an inch thick, and are welded in. The double cylinder engine which utilizes this air in turning the wheels of the car does not differ materially from a steam engine, except that its two cylinders are only two and three-fourths inches in diameter, inside measurement. The machine built by Mr. Bushnell to compress the air consists of three steam air pumps. The first and largest is merely a feeder to the second. The air that comes from it is condensed to a pressure of about six pounds. This denser air is more worthy the prowess of the second pump, which in turn crushes it into a greatly smaller compass. The third pump gives the final pressure. The gauge on the compressing machine has registered 3,500 pounds per square inch. The plungers of the second and third pumps have no heads. They are merely rods of steel forced into vessels containing oil. As the plungers move out and in, the surface of the oil falls and rises, admitting the air through one valve and forcing it out of another. It is, therefore, necessary to have the packing of the plungers only oil tight, not air tight, under the tremendous pressure. Air, like all other substances, gives out heat while being compressed, and it is necessary to cool the chamber that first receives the air from the third pump by a covering of cotton waste saturated with water. On the other hand, the expansion of the air as it is given off at each half revolution of the car engines absorbs heat, and after running the car for a short time the engine cylinders and escape pipes are whitened with frost. This coolness destroys in part the elasticity of the air as it enters the cylinders. To remedy this Mr. Bushnell will surround the cylinders with stout metal jackets, beneath which he will force air with the aid of a small pump geared to the machinery of the car. This newly-compressed air, he says, will supply heat enough to keep the cylinders warm.

The writer rode recently on the new car as far on the Whitneyville road as Mr. Bushnell could go without interfering with the trips of the horse cars. The motion was easy, and at times about twice as rapid as that of a horse car. The new vehicle obeyed the engineer promptly in starting and stopping. The distance traveled in going and returning was a little over a mile. At the start the guage registered 1,800 pounds. At the return the pressure indicated was 1,500 pounds. When the air was allowed to escape from a turned cock the roar was frightful and was as irritating to the ear as escaping steam. In running, however, very little noise is heard from the escape-pipe, because the escaping air is made to pass through a mass of ordinary curled hair. This device Mr. Bushnell esteems one of the most important of his inventions. He has no doubt that it would prove equally efficacious in deadening the sound of escaping steam.

Friends of Mr. Bushnell claim that he could never make a receiver capable of retaining air at the high pressure he had in view. The air that was in the tubes last Thursday was pumped in, he says, on the 25th of June. The gauge then showed 2,100 pounds. The pressure gradually lessened until two weeks ago, when it was 1,900. After that time a small leak was discovered. This leak was closed with a turn of the wrench, and after that not a pound was lost up to the trial, when 100 pounds was allowed to blow off to gratify the curiosity of visitors just previous to the short trip referred to.

Mr. Bushnell called attention to the small diameters of his largest tubes. He said that a pressure of 2,000 pounds per square inch would give, by calculation on the head of each tube, an aggregate pressure of fifty tons; while the two-feet heads used by the inventor of a rival compressed air motor would have to withstand an aggregate pressure of 180 tons, if a pressure of 800 pounds per square inch should be put on, as the inventor claimed was possible. The heads were necessarily the weakest parts of the tubes. A welded joint, such as his were, was usually reckoned twice as strong as a riveted one.

On a previous occasion Mr. Bushnell made a round trip on his car on the Whitneyville road, a distance of a little over four miles. The pressure was then reduced from 1,950 pounds at the start to 750 pounds on the return. A company called the United States Motor Power Company has been formed, and Mr. Bushnell is its president.

ARCHITECTURAL CEMENTS.

From "The Engineer."

Portland cement has unquestionably proved a most important gift to the architect and builder. Viewed æsthetically it was an immense advance upon the ugly red-brown "Roman" cement of Parker; still, as an ornamental material for plastering external surfaces, and casting into decorative forms it has some grave defects. Chief of these to the artistic mind is its cold ashy grey color, and the minutely porous texture of its finished surface, which is rapidly rendered darker and more gloomy-looking by the deposit in its innumerable porosities of minute particles of London smoke and soot. Portland cement makers have speculated in a desultory manner upon the great improvement which would be effected, if materials could be found not requiring more expensive manipulation than those necessary to produce the existing cement, but which should yield a product having a more sunny tint than the cold leaden color of Portland cement, one, in fact, more nearly resembling the actual shade of a clean building of the best Portland or Bath stone. There are some considerable difficulties in the way of introducing such an improvement, for so intense are the coloring powers of the peroxides of iron and manganese in combination with the earthy bases and with silica, that a mere trace of either or both of these oxides is

sufficient to remove all whiteness or purity of tint from cements produced from the materials ordinarily employed. The glass manufacturer, and to a considerable, though less extent, the brickmaker, can largely remove or greatly modify in the processes of fusion or of kiln-burning the tints of their manufactured articles; but the processes employed by the glassmaker are too delicate and expensive to be applied to the decoloration of the materials of cement, and the direction for improvement must rather be looked for in the scientific choice of the materials themselves than in any chromatic changes to be wrought in them during the processes of manufacture. In France some progress has been made in this direction. In the south a manufactory which still bears the historical name of Vicat, situated not far from Grenoble, produces, from combinations with the limestones of Dauphiny, a plastering material which has really the sunny color of those softer varieties of Bath stone which were so largely applied by Sir William Chambers and his successor, Gandon, to internal decorative carving, fine examples of which may be seen in the interior of Chambers' noble structure, the Customhouse of Dublin. It is stated on good authority that amongst the multitudinous beds of calcareous stone which crop out along the coast around Boulogne, one or more thin beds of a very light yellowish color are found which produce a cement of the desired bright tint. There are immense Portland cement works at Boulogne, but the demand is chiefly for constructive purposes upon a great scale, and little attention seems to be there given to the fineness of tint of the cement, and a very small rival manufacturer, who, we believe, was the discoverer of these fine tinted beds, was stopped by his colossal rivals, who purchased the deposits from under his feet. It may be noticed also, that in Ireland—where, as yet, we believe, all the Portland cement employed is imported, none being manufactured—there is an immense assortment from which to select suitable argillaceous limestones. These are to be found in various localities—more especially in the tilted up beds which are found cropping out at highly inclined angles for several miles to the westward of Drogheda, along the northern bank of the river Boyne. Scarcely two of these beds are quite alike in composition. There are thick beds of almost pure crystallized carboniferous limestone, and there are hundreds of various composition, none being very massive, running into limestones so clayey and siliceous that they will not burn into lime at all in the ordinary kiln. During the presidency of the late Sir John Burgoyne, as chairman of the Board of Public Works of Ireland, at a time when hydraulic lime equal in quality to that of Aberthaw was largely needed for the works of improvement then going on upon the river Shannon, a member of the Board, Mr. Radcliffe, conducted for his own information an extensive but desultory series of experiments upon the diverse calcareous minerals of Ireland that might produce hydraulic contents, and amongst these many of the beds along the Boyne were subjected to experiment, and some produced hydraulic cements of considerable hardness, and of great beauty of color. Mr. Radcliffe, however, was no chemist, and had much of the red tape of his office to attend to, and often obtained through his scientific ignorance anomalous results which he could neither trace nor explain, and which at length disgusted him, and the further prosecution of the research was abandoned. A large body of data of more or less value was, however, collected, chiefly through the intelligent assistance of Mr. Charles Scanlin. The results obtained may, perhaps, still exist in the archives of the Board at Dublin. The circumstances have so far been here alluded to, however, because the immense repertory of calcareous and silico-aluminous beds remain, we believe, still to reward with success the energy and skill of whoever shall bring them into use. Their position, as above indicated, is favorable for the establishment of a cement manufactory, the materials being abundant. Coal, though imported, is nearly as cheap as anywhere else in Ireland, and the means of distributing the manufactured article are ready. A richly colored cement, having the other properties of Portland, would soon command a large sale and introduce a new manufacture almost wholly from native

materials, to Ireland, which at present can boast of little else in the way of manufactures, except those of porter and whiskey.

Another cement is conceivable, of a decorative character and nearly colorless or pure white when in mass, which would seem eminently worthy of attention, to produce which, however, we must look in another direction than to the sedimentary rocks. Calcareous minerals, as chalk, and the white marble of Donegal, are easily obtained. The difficulty begins when we look for a material containing soluble silica in abundance, and freed from the discoloring elements of iron and manganese. Now, amongst the secondary products of volcanic districts, we have a source, as good as it is inexhaustible, of what we need. Almost all lavas, but especially the colorless, or but slightly colored trachytes, when exposed to the vapors which are exhaled from the fissures called fumaroles, are well known to all who have visited the popular wonder of the solfatera near Pozzuoli. The vapors, emitted in all similar fissures in volcanic districts, of hot steam mingled with the vapor of hydrocholoric acid, and of sulphurous acid, slowly passing by higher oxidation into sulphuric acid, act with surprising energy in reducing the hard crystalline trachytes into a soft, plastic, and often colorless mud, and by further decompositions frequently into hyalite, which in the lapse of time becomes converted into various varieties of opal, as found now in the great tufa beds of the extinct volcanic regions of Hungary. These decompositions and their results are seen in a vast scale in the siliceous linings of the Geyser basins in Iceland, in New Zealand, and in that wonderful natural volcanic museum, the national or people's park of the future, in California. In any quantity these natural compounds of more or less soluble silica, and as colorless as ice, may be had for the trouble of collection and transport. With pure limestone, and with these remarkably pure hydrated silicas, in composition with more or less of equally pure alumina, it would seem quite practical to procure a cement for internal and perhaps external decoration of dazzling whiteness and beauty, and which from its closeness of texture would not become discolored by the coal smoke of our cities, and which would bear washing whenever necessary. The eyes become so habituated to the roughish and *grenu* surfaces of Portland and other building stones as well as of cement, that fancy suggests that a fine smooth close-grained surface for the exterior of our buildings is unsatisfying to the eye. Any one, however, who will examine the façade of a large building—a bank, we believe—in Cockspur-street or Trafalgar-square—we know not which it should be called now—nearly facing and to the south-west of the Nelson column, which has been constructed of Sicilian white marble, may easily see that a smooth, hard, white external surface is quite consistent with architectural beauty, and possesses immense advantages in the smoky atmosphere of London.

For internal decorative purposes it would be needless to enlarge upon the value of a material that would possess far greater beauty in color and texture than plaster of Paris; would be non-absorptive, little attractive of smoke, not easily scratched, and which might be washed again and again. Every one who has examined the interior of the decorated rooms of Roman villas at Pompeii will have been struck by the smoothness, density, and hardness of the colored surfaces of stucco, upon which the plain color and fresco paintings of the walls have been laid. The common belief is that this stucco has been mainly formed of lime mortar, more or less mixed with *gesso* or plaster of Paris. We are, however, by no means convinced that the true composition of the material has been revealed by the imperfect analyses and carless examinations of modern times. It is somewhat difficult to obtain specimens for examination, for every morsel, however fragmentary and valueless, of this or of any other material to be found in the rubbish heaps of Pompeii is rigidly prevented by the guardians from being removed by the visitor who can only secure a specimen by the troublesome and round about process of obtaining an official order from Naples. The observer is, however, struck by the remarkable fact that polished fragments of various different and brilliant colors abound in the rubbish heaps of Pompeii which, after

eighteen hundred years' exposure to air and moisture, and to the corrosive vapors which everywhere permeate the porous soil about Vesuvius, are as hard, smooth, and brilliant as when they left the hand of the workman. A more careful examination than has yet been made of these stuccos might yet reveal the process of their formation, and perhaps show that the soluble silicates produced by secondary volcanic reactions, such as we have spoken of, were employed in their formation.

The economic uses to which several volcanic products may be applied open a vast and, as yet, almost untrodden path of useful discovery. One of the valuable uses to which these may be employed is largely known to the house decorators of Rome and Naples. Certain trachytes when fully decomposed by fumarole vapors, finally fall into an impalpably fine and soft powder without coherence, of various beautiful delicate pearly-white tints, which are used as the coloring material for ceilings and plastered walls in place of whiting when applied with size. The character of delicate and slight broken color thus given is greatly superior to the eye of taste, to the cold dull white of our whitened ceilings and walls. It is also in texture much more satisfactory to the eye. The lime beds of tufa which abound around Vesuvius and in Auvergne, are to be found of every color and tint, from pure white, such as is the "domite" of the Puy de Dôme, to buff, yellow, red, and brown, into almost coal black; indeed all these tints occur together in super-position in the masses of tufa, generally of impalpable fineness, over which one ascends to the crater of the volcano in the Lipari Island of that group. A miserable, abortive attempt has for many years continued a struggling existence to extract such chemical substances as boracic acid, sulphur and alum, from the ejecta of volcanoes, but neither these, nor, so far as our knowledge extends, in any other volcanic district in Europe, has any well-considered attempt been made to utilize for architectural or other economic purposes the vast deposits of colored and pulverulent tufas—unless, indeed, we except the use made for the production of an hydraulic cement from certain tufas which are dug out by excavating into certain parts of the huge cone of Sarconi, in Auvergne. There can be little doubt that many volcanic tufas would consolidate by mere mechanical pressure, and a little baking into tessaræ, of various sizes that might be employed for laying ornamental mosaic flooring of much greater beauty and far cheaper than our English encaustic tiling, which by the large size of each tile, in proportion to the apartment which they floor, and the harsh and gaudy coloring but too generally offend a cultivated eye. Whether these or any other tufas would *per se* by pressure alone become sufficiently hard and coherent or not, it does not admit of doubt that by suitable admixture with calcareous or siliceous matter, or both, they would become so. The manufacture would be well suited to Italy and Central France. In Great Britain we are fortunately exempt even from dying-out volcanic action, although we have in the products of remote geological epochs, especially in the North of Ireland, abundant beds of lavas and trachytes which would readily suffer decomposition into soluble silicates if exposed to sol fatara vapors.

May we not artificially produce and utilize these vapors? Hot steam we can have at the expense of some coal. The alkali makers of Widnes, Glasgow and Belfast, as an educt of the process of decomposing common salt by Le Blanc's process for the purpose of making "salt cake," as it is called, and ultimately crystals of carbonate of soda, evolve millions of tons of hydrochloric acid vapor which used to fly into the atmosphere—until that nuisance was remedied by legal enactment—and the acid vapor compulsorily condensed to run into the sewers to waste. Sulphuric acid or vitriol is at hand in all these vast works as a necessary element for the decomposition of the chloride of sodium. We have here, therefore, on cheap terms, all the conditions requisite for the production of an artificial solfatara where we please, so that by the help of a little hot steam, hydrochloric acid, and sulphurous acid vapors commingled, we may at an extremely small cost decompose and convert into useful products such trachytes as may be found nearest and most suitable.

THE ORIGIN OF METALLURGY—THE BRONZE AGE.

From the French of EMILE BURNOUF, by CHRISTOPHER FALLON, A. M.

Translated for VAN NOSTRAND'S MAGAZINE.

I.

We are ignorant as to the date of the first appearance of mankind; we have no foundation upon which to rest the chronology of the primitive times. History dates only from yesterday, and yet, among the different nations, presents but fabulous origins. There is no more reality in the first facts related by Titus Livy than in the genealogies of the Grecian heroes. Adam and Eve are an agreeable myth, borrowed perhaps from Persia in the times of captivity; their descendents are the personification of families or of tribes. Grecian chronology goes back about six thousand years prior to our era, but is likewise preceded by a long mythological period. The same may be said of India and China. After all, what are six thousand years? Already have a hundred passed since the French revolution, and does it appear long to any one? Now-a-days events follow each other very fast and progress is rapid, because we possess forces, both physical and moral, of enormous power, by means of which we transform the earth and ourselves. When our ancestors possessed them not their advances were slow, their achievements small and casual. How can the ocean be traversed, or a large sheet of water crossed without boats, and how can we construct boats if there are no tools of iron or some substance sufficiently hard to work wood, to adapt the pieces and render them imperveable to water? Let us consider the objects we make use of to-day to clothe, shelter, nourish and convey ourselves from place to place, to procure light, heat, books and so many products of science and art which adorn our households. It will readily be seen that there is not one which does not suppose the possession and successful employment of the metals. We are now all aware that men have not known them at all times. For a great number of years, they did not possess any, except perhaps a few grains of gold which nature spontaneously gave them, and which they collected here and there on the banks and in the channels of rivers. It was this period which has been called *The Stone Age*, and the tools those unfortunate men have left behind them, as evidence of their industry and necessities, are all made of hard stone, of silex, of diorite, of absidian and of trachyte. This long period of the infancy of man is attested by the strata in which these objects are found, buried beneath mounds of earth which have required centuries for their formation; but the actual geological period had not yet begun when man was already in existence living among mammoths, bears in caves, and other animals now no longer to be found. In the first place it was necessary that a man having selected a stone on which to put an edge, should strike it with another in order to scale it. Thus were the first hammer and the first hatchet made; and all other instruments being made in like manner, have given the name of *The Period of Unpolished Stone* to the era during which this rudimentary industry lasted. Little by little it was found that certain stones could by means of continued rubbing wear others, which were even harder, and so friction was substituted for percussion in the manufacture of tools. In this way sharp hatchets and scissors were made; round hard stones were bored and handles inserted. Smaller stones of finer quality or brighter color were shaped and pierced and then used as beads. Arms were made in the same way. It was this second period of humanity which has received the name of *The Period of Polished or Neolithic Stone.*

From the beginning, or at least from an early date, men attempted to mould clay into uses of different kinds. This work was done by hand during the entire age of stone. The potter kneaded the clay with his fingers, the impression of which is yet seen on the pottery of those early times. It required constant observation and new means of action to enable the potter first to discover the value of the movement of a wheel, and then to construct one. In fact the turn-

ing lathe seems to have been unknown during the whole period of which we speak, but the baking of vases dates far back, for from the time that men could light fires, they observed on their hearths pieces of argil become insoluble by the heat. The black, red or yellow clay which nature furnished them in many places, enabled them to color or paint these roughly made vases; they then polished the surface yet soft, by means of a stone burnisher and engraved fantastic figures thereon.

Then came the first metal, which let us say was the common metal, copper. The knowledge of gold certainly preceded that of brass, because gold is found in its natural state in many countries. It no doubt was the same with silver, the extractions of which is not very difficult; perhaps the same should be said of lead, for from the time globules of metal were found in the ashes of the fire, the man who noticed them, must have wanted to know the ore from which it was extracted, and having found it, must have sought for more in the mountains.

Substances which are producible in hearths, by the mere burning of minerals, must have been first discovered, as lead and glass; artificial glass, usually blue, is found among the objects of personal ornament of the most ancient times. On the other hand, when the extraction of a metal requires a high temperature, or a chemical operation, it may be conceded that such a metal was discovered long after the others and after a number of ineffectual attempts. Copper is found native, but in very small quantities; copper pyrites resembles gold, still the metal is obtained only by complicated operations, as is the case also with tin. Finally after obtaining these two substances, it is necessary, in order to form bronze, to make a fusion—which is attended with difficulties. The bare idea of uniting two metals does not readily present itself to the mind, and when once conceived it is yet essential to learn in what proportions they must be used in order to form a new metal, more useful than either.

Bronze appeared in the West when the art of polishing stone had arrived to a state of perfection. We have in our museums instruments of hard stone made anterior to the appearance of bronze, which our own workmen would not make better nor in any other manner; only they would probably make them faster, for they have means of action and processes which the ancients did not possess. Bronze, at first scarce, became more common in the course of time. Those fabricating it could dispose of it in other countries only in exchange for other objects of the same value but of a different kind. These objects of exchange caused a demand which could be supplied only by discovery, or by obtaining them elsewhere in sufficiently large quantities to give rise to commerce. The discoveries of which we are about to speak have proved that the quantity of bronze kept increasing, that with this new metal many instruments were manufactured which were previously made of stone, that new ones were invented, and that a time arrived when the substitution of bronze for stone was, so to speak, complete.

The Bronze Age was for a short time co-existent with the period of polished stone. There is then a period of transition when these two substances were, in a measure, blended together, and might be comprised under the same title in the age of stone or in that of bronze. It would be a mistake, however, to suppose that metal caused the hard stone to disappear entirely when the superior qualities of the former were discovered, as stone continues to be used for many purposes in many countries where neither bronze nor even iron has as yet supplanted it. Thus those small double-edged blades made of obsidian or silex, known as knives, still in use in the Grecian peninsula, in Asia minor, in Palestine, and no doubt in many other countries, are fastened to pieces of wood and used by the peasants to thrash their wheat or cut their straw. They are of the same shapes as in the bronze age and are made in the same way; but the predominance of metal over stone, and the abandonment of the latter, in most cases in which it was employed, characterize the long era which followed that of transition and which constitutes the bronze age properly so-called. In the same way that this metal was substituted for stone, it happened that a new metal concurred with bronze, and was used instead wherever there was a decided advantage in so doing.

Discoveries which were made only twenty years ago, and which since then have been repeated throughout Europe, have enabled us to fix the period of transition from bronze to iron. It differs from that which has been called the first age of iron, and which has, for a long time, been well ascertained. During the latter, iron already takes the first rank and awaits only to be brought to a state of perfection. The transitory period is marked by a slow and progressive substitution of the new for the old metal, and by a reciprocal influence from one to the other. When iron first appeared in Europe, it met the same fate which bronze a few centuries previously had experienced. It was a rare and precious substance and lost its value only by its increasing abundance, and when it could be converted into tools, utensils and arms, which were formerly made only of bronze. The oldest objects of iron found are bijoux and ornaments, for even in those early times there were rich and poor men, and those alone could obtain articles of iron who had other valuable objects to exchange. Do we not see the same thing in our own day? We assisted, a few years ago, if not in the discovery at least in the economical extraction of aluminum. This metal until then confined to laboratories, became an industrial product, but as the preparation is yet expensive it is worth twice as much as silver, and is employed in making ornaments and fancy articles. Yet it is not less common than iron in nature; it is the base of all clays and possesses qualities which can—which ought to make it preferable in certain cases to silver, to brass or even to iron. It needs but new processes of extraction to render it as abundant as the latter.

Iron has not entirely supplanted bronze, as the latter is still much used, nor would aluminum and all the other metals cause iron to be abandoned: but a new substance may answer many purposes better than those that have preceded it, and for this reason be preferred. For a long time hatchets were made of stone, but were set aside when they could be made of bronze; bronze hatchets were the only ones to be found for many centuries, but were also abandoned when iron ones became sufficiently abundant to compete with them in the market. The period of transition from bronze to iron is well characterized in many ways, of which we shall speak hereafter. There is no doubt, at present, of the reality of this change, and it is even becoming apparent how this transition was accomplished, the course the metals have taken to spread from one mart to another, until they have reached the most remote countries of Northern Europe; but before exhibiting these grand discoveries of our day, I must give an account of the progress which science has made in the study of ages anterior to any history.

II.

We need not here repeat the list of discoveries relative to the age of stone and to the men of those primitive times. The savants of the first empire and of the restoration had denied the existence of what was then called the fossil man. Science and religion united in discrediting even the mere possibility. The discussions which arose when Boucher de Perthes announced the discovery of the remains of such a man in the old alluvia of one of the northern departments, have not yet been forgotten. His discovery was followed by the sarcasm of some and the fanaticism of others, until the day when a new generation of savants recognized their authenticity. A short time afterward skeletons of fossil men and remains of their works were found on all sides. The name of Lartet is connected with the exploration of the caverns of Perigord and Languedoc; those of Tomsen and Wilson with the prehistoric antiquities of Denmark; and that of Keller with the lacustrial habitations of Zurich. Since then Boucher de Perthes is regarded as the originator of a new science, which forms the connecting link between the geology and archæology of historic times. This science though of recent date is always possessed of a great number of observed facts, is methodic and well defined, and its general results are already perceived. Among those who concurred in these first developments there will be found very few erudite men; they are mostly scientific men, geologists, physiologists, engineers, chemists, and perhaps amateurs who delight in this science as a past time to beguile their leisure hours

away. Texts were for a long time the only means of investigation; but the most ancient texts are, in reality, modern, if they are compared with those long periods of which mankind in its infancy passed over. The most ancient Grecian authors, those who under the real or fictitious name of Homer, have bequeathed the Iliad and Odyssey lived in the iron age, they related events which occurred many years before, and if real, were accomplished, according to all appearances in the bronze age. This does not prevent the author of the Iliad, and especially of the Odyssey to put iron in the hands of his heroes; thus the poets attributed to the past what was before their own eyes, but which the past never knew. Egypt had not yet begun to furnish those documents which are now being found; it was not known that the first four dynasties at least are anterior to the knowledge of iron in that country. The hymns of the Veda, to serve as scientific documents, should in the first place be classed according to a chronological order and referred, if possible, to certain and determinate epochs. India seems far from being able to throw any light on this subject. As to Genesis, it is known that its origin is a matter of discussion among the learned, and if some, true to their faith, attribute it to Moses, others reject its authenticity and consider it as formed by the union of two opposed traditions into one book. Be it as it may, and admitting the authenticity of Genesis, it is at least certain that its author had little knowledge of the bronze age, and still less of the stone age, for it is said that Tubal-cain, the first metallurgist who is mentioned, "was maker of all sorts of instruments of brass and iron." In fine, the ancient authors cannot have had correct ideas of the primitive times, composed perhaps of decades of years when writing was not yet in existence. It is possible there were traditions handed down from year to year, still the passage from the Prometheus of Eschylus, in which mention is made of the first men, of their living in caverns, and of the discovery of metals, is too vague to serve as a basis for scientific induction. In fact the ancients were not in a situation so advantageous as ours with regard to the past which there were no documents to record, as they neither had the means we possess, the innumerable facts which all the countries of the world can furnish, nor the capacity of acting in concert as now throughout Europe by means of communication and typography.

The Greeks made no underground searches. The Romans robbed a great many tombs, not through love of science, but to obtain the valuable objects therein, which have been reburied or have disappeared with them. The Roman church which followed the empire has never favored the positive sciences. The middle ages were taken up with metallurgy, but their end was that of King Midas; the philosophers stone was to convert all the metals into gold. The modern spirit which may properly be called the scientific spirit, after having learned with Bacon and Descartes its real rudiments has steadily advanced in a series of discoveries. Possessed of the abstract sciences it has been able to unite conjecture with reality, and found natural philosophy and chemistry.

It then gave birth to that new study, whose subject is human beings; to the physiology of plants, of animals, and finally to the science of man, of which prehistoric archæology forms the first chapter.

Farmers and workmen had for a long time known of the existence of instruments of bronze, and had gathered and sold them before the savants thought of collecting them and organizing a museum. The first collection made was that at Copenhagen. It was Thomsen who as early as 1836, classified all objects dug from the dolmens, barrows and mounds of Denmark, and founded the museum of Northern Antiquities, the finest prehistoric collection in Europe. A certain Swede, Sven Nilsson; profiting by Thomsen's work, and by his own knowledge of the barbarians of Oceanica and of other countries not yet civilized, united their industrial works with those of the ancient Danes, and from 1838 to 1843, introduced the study of comparative ethnology. It is not to be supposed that the savages of to-day are descendants of the ancient inhabitants of Europe, but their ways of life are the same, and they make use of the same means to satisfy their wants. There now exist colonies which do not know

the use of metals, or which obtain them in small quantities and look upon them as objects of personal ornaments; they have nothing to exchange in commerce with the rest of the world.

It was Thomsen and Nilsson who distinguished the stone age from the bronze age; they had found in the Northern countries a certain class of tombs in which, besides skeletons and rough pottery, objects of stone are found, but there were no traces of any metal. In others bronzes were found to have served the same purposes as stone, and to have been substituted. In others again appeared articles of iron almost similar in form to those of bronze of the other graves. It is evident that if the men of the first period had had bronze, they would have used it in preference to stone, while those of the second would have put aside bronze for iron.

Thus the first distinctions of the prehistoric ages were established and in succeeding years were confirmed. Two years after, M. Worsaae, a Dane, in his book on the ancient times of Denmark, set to work to explain the numerous discoveries of the bronze age made in his country. Notwithstanding this, until the year 1853 there were but few works added to the corpus of a science which seemed to be confined to Northern Europe. It is but necessary to recall the memory of Mr. Simon, of Metz, regarding the discoveries of Vaudrevanges near Sarrelouis; there were found four hatchets, one mould, one glave, one horse bit, fourteen bracelets, and many other small objects all of bronze. It was a real treasure, but added little new to the science.

Switzerland ranked next. In 1853 there were found in the lake of Zurich, and shortly after in the other lakes of that country, dwellings built on stakes driven in the ground, which have received the name of *palafittes.* With this discovery of great scientific value, we find the name of Dr. Keller associated. It confirmed those made in Denmark and Switzerland ten years previously. These houses were not situated along-side of each other, but superposed, and presented the three prehistoric ages. Among the ruins of the upper layer was found iron mingled with bronze; in the middle layers just beneath, bronze only together with objects of stone which the metal had not yet replaced; and lastly, in the lower layers on the bottom of the lake were found articles of stone only, without any metal whatever. At the same time the progressive march of civilization was noticeable by the excellence attained in the art of moulding either pottery or metal. There was no longer doubt as to the succession of ages, nor as to the essential character of each. The lacustrial habitation of Switzerland proved that these three periods of ancient civilization were not confined to the North, but were spread in more central countries.

That same year (1853), was favorable to the prehistoric sciences. While M. Keller was sounding the lakes of Switzerland, there was discovered at Villanova near Bologne, a necropolis, which has been termed, perhaps not entirely correct, proto-Etruscan. It was examined and described with exceeding care by Count Gozzadini, who made it known the following year, and who has since then made numerous other discoveries. The nature of the objects found in that cemetry showed that it belonged to a time posterior to the last period of bronze, but anterior to the Etruscans, with whom its dead had till then been confounded. It was after the discoveries of Villanova that *the first iron age* was assigned a place in science; this age had followed the period of transition from bronze to iron, corresponding to the upper layer of the palafittes, and had perhaps immediately preceded the Etruscan period, which extended down to historical times. Thus the past and present of man seem to be connected by a series of links, so to speak. Archœology is properly a branch of history, and is probably the most substantial part, as it is founded on real facts and not on mere reports often altered and sometimes falsified. Its commencement is connected with prehistoric studies, as the three prehistoric ages are connected two by two in their order of succession. In ascending from age to age, you arrive at the period of unpolished stone; beyond that there is probably a long term of years ending with a man of the quaternary, may be of the tertiary period; that is to to say, with the geological epochs prior to the one in which we live.

It is at this stage of science that theories begin, as those of Darwin on the origin of the human species, and its animal forms which have preceded and followed it.

In 1857, M. Troyon, in publishing the discoveries of Keller, called attention to the problem regarding the origin of bronze; but to solve it, it was necessary that a science as yet of recent date should be further developed by new facts, and throughout many countries. After Switzerland Savoy and Italy made the largest contributions to the study. Professor Desor the following year sounded the waters in lake Neufchatel, and after M. Morlot had, in 1860, published in Switzerland the discoveries made in Denmark and Sweden, a spirit of searching was manifested throughout the central countries. Messrs. Fastaldi and Desor that same year visited the lakes of Lombardy and found in the tour bières of the major lake objects similar to those in the lakes of Sweden. In lake Varesa, in 1863, Messrs. de Mortillet, Desor and Stopani recognized the period of transition from the age of stone to that of bronze. The palafittes were noticed only in later years around the fortress of Peschiera.

Since 1862, Messrs. Strobel and Pigorini have found not far from Parma, deposits of loam, known to husbandmen as *terramares*, and therein detected the remains of the old lacustrial habitations; in fact the stakes still remained, and were surrounded by organic matter; from the appearance of the alluvium it was evident that water had remained in the low portions of Emile, and that formerly there had flourished a civilization identical to those of the Swiss lakes.

We cannot here cite the names of all those who, since 1860, have contributed to the advancement of prehistoric studies, their number has increased in proportion as the increasing interest of research extended, and a method of procedure was adopted.

Suffice it to say that searches were made throughout Europe, and that the desire to contribute to the progress of the science of man, has called forth many exploring savants throughout western Europe. In Austria, there were Ram-auer and de Sasken; in Hungary, Romer; in Ireland, Wild; in Russia, Aspelin and Bogdanof; in England, Evans, Franks, J. Lubbock. In France, we have already mentioned M. de Mortillet who is at the head; to this name we must add those of Messrs A. Bertrand, Costa de Beaurregard, Cazalio de Fonduce, l'Abbe' Bourgeons, and M. Chantre from which we have derived much of our information.

In 1862, Napoleon III founded the Museum of St. Germain, which was established for the purpose of collecting the Gallo-Roman antiquities; the history of the Cæsârs, in connection therewith, became a study of especial interest to the Emperor. The director was not slow in enlarging his plan and obtaining more help, and was soon able to offer to the public a prehistoric museum which well compared with the one at Copenhagen. It is to be regretted that a collection of this kind is 20 kilometers distant from Paris, which makes it inconvenient for the public; and the scientists do not derive the benefit they ought, so that it is not frequented very much.

Two years following M. De Mortillet commenced the publication of his "Materiaux pour servir a l'histoire de l'homme," a work of great interest which, in 1869, passed into the hands of M. de Cartaihœ. Since 1865, on the suggestion of M. de Mortillet, there was started an ethnological congress which is composed of the savants of Europe; this congress changes its place of meeting from time to time, and has already assembled, besides at Spezzia where it originated, at Neufchatel, Norwich, Copenhagen, Bologne, Brussels, Stockholm and Pesth; they propose holding their next sessions at Athens, Smyrna or Constantinople.

The impetus given to the prehistoric studies by these three French institutions, was increased by the universal Exposition of 1867, where a number of the products of primitive industry was gathered together. The Exhibition of 1878 will be still more important as it is intended to bring together entire collections from all countries. Germany alone will not be represented.

The number of books and memoirs relative to the ancient ages and particularly to the bronze age, is considerable.

There are very many public and private libraries throughout Europe, so that it is next to impossible for one man to visit them without devoting much time and money. The need of statistics, as full as possible to give all the learning available to aid in future discoveries, was felt. The demand was supplied by M. E. Chantre's admirable work entitled the *Bronze Age*. In one of the three volumes of which it is composed, there are only tables in which are classed in methodic order, all the objects of the bronze age found in France and Switzerland with indications of their orgin and where they can be seen to-day; there are at present almost 33,000 specimens. The other volumes contain much information of the other parts of Europe from which objects of bronze were gathered. If a work similar to that of M. Chantre was devoted to each of them, it might be easily believed that the conclusions of this savant would be confirmed, as they are founded on a thorough knowledge of all European collections, although his original intention was to have merely given statistics. As no work of this kind had yet been published on the prehistoric ages, it is to be expected that this one will form an epoch in the science and will be a starting point for new discoveries to begin.

III.

We will now speak of the places where products of bronze industry were found. The first steps of science were difficult and uncertain, because discoveries were made by mere chance, and by inexperienced men, who very often sold their antiquities by the weight, and sometimes destroyed them even. Thus in 1859 on a farm of M. de Gourgue near Bordeaux, "the husbandmen on returning from the fields, told their master that during the day they had found a corpse, that they tried to smash its head with their sabots, but it was so big and hard that they could succeed only with their spades." They brought back with them however, a hatchet, a sword, golden threads and fragments of pottery. The following occurred in 1865 at the celebrated prehistoric foundry of Larnaud (Jura), "Brenot fils, while digging potatoes, discovered a piece of green metal which excited his curiosity and that of his friends. They set to work and found a quantity of objects of the same metal within a plot one meter square. The next day Brenot père took a specimen to Lons-le-Saulnier, a brazier, who told him that the bronze was worth forty cents a kilogramme. On this man's suggestion, Brenot offered his treasure trove to an amateur of antiquities, M. Z. Robert, who did not hesitate to take them. There were about eighteen hundred pieces, weighing 66½ kilogrammes." All this bronze came near being thrown into the crucible of the founder. It is now in the museum St. Germain, and is one of the most interesting collections. One more incident may be given. The ancient foundry of Vernaison (Rhone) was found in 1856 on the property of M. D——. The total weight of the bronze was 16 kilogrammes, but the director of the Lyons Museum at that time, retained only a small portion. "We have selected," said he, "the complete, or mutilated objects most worthy, to adorn the museum, the rest was returned to M. D.—, who proposes to have cast a commemorative urn, with an inscription recalling the event of the discovery." Notwithstanding the dangers by which the prehistoric science was surrounded, the bronzes in France and Savoy are already so numerous and so well characterized, that M. E. Chantre has been able to class them into categories which we divide in two groups; the *visible strata*, and the *hidden strata*. The first comprises grottoes, dolmens and palafittes or lacustrial habitations; the second, treasures, foundries, isolated stations and tombs in open fields.

It is well known that caves formed the first habitations of man, not only during the stone, but also the bronze age. Throughout Europe inhabited caves are found. The most interesting perhaps, are those of Central France and on the banks of the Meuse. The latter have the advantage of being in three planes, representing three successive risings of the river which irrigated its banks. They present supposed layers of human remains of three consecutive epochs; that of metal, of polished stone, and of rough stone. The latter which is beneath the other two, is no longer found on a level with the other two layers which were then beneath the

water, for the Meuse at Dinant was not less than three leagues wide. Among the human remains there are bones of mammoths, hyenas, rein-deer, animals which were then in France and Belgium. The inhabitants of the caves made earthen vases, but knew not the art of baking them, although they had fires. M. Dupont, (L'homme pendant l'age de la pierre) from whom the following is obtained, estimates that during the period of the mammoths, the width of the Meuse at Dinant decreased from 12 kilometers to 400 meters, which is the distance of the caves in the center. To-day it is but thirty meters. The middle layers just beneath those of the mammoth, correspond to the period of the rein-deer, the grottoes, which are termed pits of the Mitons, of Chaleaux, of Frontal, are striking examples. The remains of human industry are buried beneath a bed of yellow clay which covers them. In these no bones of mammoths or hyenas are found, but only those of some species now living; the wolf, fox, deer, wild goat and rein-deer. There are not yet any polished stones; there is no trace of metals; the potteries are made by hand but are not baked; small stones, pieces of bone, teeth of animals, or fossil shells with holes, composed the ornaments of those people. The third layer, corresponding to the inferior caverns on the borders of the Meuse, is that of polished stone; it is the epoch of dolmens and lacustrial cities of Switzerland, Savoy and Italy. Yellow clay disappears, the rein-deer, elk, wild bull, and castor have all disappeared. The hatchets are made of polished stones with holes for inserting handles; the potteries are now baked. This epoch has left behind but little remains in caverns, but much is found in the earth of the fields. It is here that bronze makes its first appearance, and though scarce in Belgium, is found in great quantities in Central Countries. The caves of the bronze age in France and Savoy are of two kinds, those used as dwellings and those, whether natural or artificial, for sepulchral purposes. As on the Meuse, the inhabited pits of the middle states are found along rivers, and belong generally to the period of transition from polished stone to bronze. They are scarce, and among the most important are those of Saint Saturnin, a large neolithic station above Chambery, those of Savigny near Albano, of la Salette, and of Louvaresse (Iseria). The people of the neolithic period who witnessed the arrival of bronze inhabited the plains, and often the borders of rivers. The banks of the Saone furnish us with many stations, of which the successive epochs appear in superposed layers; it is especially at the confluence of streams and about fords that they may be perceived.

Where the waters were tranquil, and produced but few changes, that is to say, near the lakes, the men of that period no longer used caves. They deserted terra firma and built houses above water, resting on piles. None are seen on the steep banks of lakes as the water is there too deep, but they are found on shallow banks of sand or earth where the water is not profound, as in fords of rivers. What could have induced those men to isolate themselves in the middle of these lakes? We have not yet learned, but it is to be hoped that new observations will solve the problem. However it may be, we perceive that this custom lasted a long while, as the palafittes of the Alps comprise not only the epoch of bronze, but those which had preceded it, and those also which mark the arrival of iron. There are palafittes of the stone age at the lake of Zurich, of the bronze age at Limau, of the iron age at Neufchatel, and each of these periods is well characterized. There are certain lacustrial habitations belonging to the two periods of transition which mark the beginning and end of the bronze age, so that it is at least certain that the custom of living over water, continued without interruption for a long time.

As there were found habitations built on piles in the north and center of Italy, it would be interesting to explore the lakes of Central Europe, of Greece and Asia minor, and determine how far the custom extended.

The men of the stone age consecrated natural grottoes for burial purposes, while they also made use of caves as dwellings. Thus on the Meuse, the small cave of Frontal was used as a cemetry for the men who dwelt in the cave of the Noutons. This mode of living was still existing at the appearance of bronze.

This is proved by the "Grotte des Morts" near Sauve (Gard). Since 1795 d'Hombre Firmas had called the attention of geologists to this cave, but it was examined only in 1869. M. Tessier died during the first clearing out, which was afterwards accomplished in the name of the Scientific Society of Alais by Messrs. Cazalis de Fondouce and Ollier de Marichard. The cave is a sort of vertical well dug out by nature in a crevice of inferior lias. From this there have been dug a large number of bones of men, foxes, wolves, wild boars, horses, sheep, a complete funeral accoutrement, composed of arms and tools of silex, bom, or deer's horn; a quantity of jet jewelry or of black or green marble, spath and Alabaster, an awl of bronze and many iron pearls, many of which were left behind with the rubbish. We will also mention among the natural caves of the first bronze period those of Labry and Baniere (Jard) which have brought to light objects similar to those already found, besides a poignard, ear-rings and bracelets of bronze, and the caves of Gonfaron and Chateau double (Var). That of Saint Jean d'Alcas (Aveyron) discovered in 1838, was searched in 1865 by M. Gazalio. It is partly artificial. At the entrance there had been placed two large arched stones supporting the roof and forming a triangular entrance. One unfortunately has been taken away by the owner of the cave, and used as a door-step to his kiln. Among the numerous objects thrown out with the dirt by the same person, there have been picked, mingled with bones and silex, two hatchets of polished stone, pearls, a spiral and bronze ring.

The artificial sepulchral grottoes have received the name of covered alleys (alées convertes). They are especially found in Provence, dug out of the small calcarlous masonry-works which appear as islets in the fertile plains of Arles. They consist of an oval gallery open above; the walls are inclined towards each other; the top being covered with large flat stones which must, in the first place, have been covered with earth. One of them, the Grotto of Cordes, which is also called the grotto of fairies was in turn supposed to be a Gallo-Roman cave, a Saracen prison, a Druidic monument, and, lastly, a sepulchral Grotto of Asiatic or Phœnician origin. "You first of all descend" says Mr. Cazalis, "on large rough stairs into a fore court, uncovered at present, which is in the shape of a sword; from thence you proceed, through a gallery six meters long, into the cave proper. At the mouth it is 3.80 meters wide but narrows in the rear; the walls are sloping. This trench, which is twenty-four metres long, is covered by inclined stones and the whole covered by a tumulus which is much worn. The total length is not less than 54 meters." Unfortunately, the funeral outfits of this cave were scattered, so that the epoch cannot be determined, except by its resemblance to the Grotto of Castelet in the neighborhood. The latter contained sixty centimeters (2.6634 inches) of earth and gravel, brought, to all appearances, from Gardon. On this lay the bones of about ten men, together with instruments of silex and bronze, and a saucer of pottery made by hand. For a long time *Dolmens* were looked upon as Druidic altars, a vague term which with the words "Celtic" and "Gallo-Roman" is indiscriminately used. Since they have been found, not only in Western Europe, but throughout the whole Continent, Africa and Asia, new theories have been current. Some scientists have looked upon them as spontaneous transformations from caves; others thought they recognized, from their distribution over the old Continent, the migrations of a wandering tribe, which, driven from Central Asia, would have followed the Baltic, stopping in Scandinavia, and which would then, driven from the Northern countries, England and Ireland, arrive in Gaul, then proceed to Portugal, and finally to Africa. We do not suppose that dolmens have as yet been the subject of sufficient observation in Africa and throughout Asia, nor even in the different parts of Europe, that any theory should already be substantiated.

The monuments which have received the appellation of megalithic, nearly all belong to the period of polished stone; still a large number date from the appearance of bronze. Those of the North are generally the oldest; and if we may judge of their relative dates by the quantity and quality of bronze which has been obtained, their antiquity

diminishes in proportion as you descend from North to South. This does not prove however, that dolmens originated with a race descended from the Northern countries; it would on the contrary indicate that bronze brought from the Mediterranean countries, reached the North only by slow degrees. There are 147 dolmens in the South of France in which bronze has been found: they are mostly situated in the region of Cevennes, a short distance from the Mediterranean. Several dolmens from Marne and the environs of Neufchatel have also yielded some. Those of Bretagne, with the exception of a few in which a little metal was found, belong to the neolithic period. The 147 dolmens in which bronze was found mingled with objects of stone, pottery of the second period and other objects which will be mentioned further on, form but a minority of the great number which have been explored. In the South of France alone, 700 have been opened in Ardèche, 300 in Aveyron, 160 in Lozere. It may be taken for granted, that if all belong to the period of polished stone, the people who built them witnessed the arrival, in small quantities perhaps, of the first common metal. If they had had it in abundance, they would in all probability have made arms, instruments and even ornaments of bronze instead of stone, shell, horn, or bone, for with a silicious saw they could accomplish in one day of hard labor, what with a bronze saw they could do in an hour, with an iron saw in a few minutes, and in a few seconds with a steel saw impelled by mechanical force. Let us suppose it is yet the custom to bury with a person the objects he has used during his life time, and that in five or six thousand years our graves should be opened, many circular saws would be found in England, France, Switzerland, Germany, but few in Italy, especially towards the South, still fewer in Spain, one or two in Greece, and not one perhaps throughout European and Asiatic Turkey. We do not, however, notice any migrations in our midst; the industries themselves are propagated, but the people do not migrate; a few men passing from one country to another suffice to introduce new industries. The composition of dolmens is uniform, only that bronze increases from North to South; it seems then that there existed in the Mediterranean regions, or beyond, a country from which bronze is brought and distributed through the Northwest of Europe.

We must now speak, from the numerous facts collected and classed by M. Chantre, of the beds of bronze which were hidden under ground, and brought to light by mere chance. They are of two kinds; the *foundries* and the *trésors*, to which may be added certain stations or centers of habitation as yet not well classified, and a number of tombs in open fields, whose presence there is nothing to indicate. A foundry consists ordinarily of a mere cavity dug out of the earth, and contains more or less complete the materials of a bronze-founder; ingots of metal, refuse and waste metal, ashes, fragments of things of little value or worn out, or defective, and, finally, crucibles, moulds, pincers, and sometimes even new objects coming out of the moulds and incomplete. Many of such foundries have been discovered in parts of Europe, especially in France, Savoy and Germany. Should the place and statistics of each be desired, I would refer the reader to the book above cited. The foundry of Larnaud may serve as a specimen. I have already stated how the son of Brenot the farmer, discovered it in 1865, and how, when offered by his father to a brazier of Lons-le-Saulnier it was saved by M. Zephirin Robert. After having been exhibited during the Exposition of 1867, in a store on the Boulevard des Filles du Calvaire, it was bought for the Museum of Saint-Germain. The case in which it is exhibited has been classified and labeled by M. Chantre who, in his work, gives a catalogue and full description. The value of the collection obtained from Larnaud, consists in this, that all the pieces which compose it are contemporaneous : there are 1485 such pieces, and the epoch to which they belong is evidently the end of the bronze age. This is what is shown by a comparison with those of the other foundries, and especially with the objects obtained from the palafittes of Savoy. Throughout, the last epoch of bronze is characterized by traces of the hammer, by the presence of metallic plates or leaves obtained by concussion and not merely by casting. On the other hand,

that which links the workshop of Larnaud with the age when bronze was the only common metal are the cold chisels made of hard bronze to cut bronze, as steel cuts iron. But since bronze is softer than iron, can it be doubted that cold chisels would have been made of iron, if the latter metal had been known or was at least abundant? We will give further proofs showing more clearly the epoch to which we must refer the foundry of Larnaud.

There are other foundries belonging to this period, among which we will mention that of Poype, situated on the heights overlooking the Rhone to the South of Vienna. A portion of the bronze had been sold to a merchant of Lyons, at the price of old brass; it was bought by M. Chantre who, on precise indications, renewed the search and was able to duplicate the products. The foundry of Goncelin is also situated on the heights adjoining the Iser, as well as those of Thoduse and Bressieuse. The largest portion of the other stations of this kind are in the neighborhood of rivers, and probably at a short distance from the places then inhabited. What is probably the most remarkable is their uniformity throughout Europe. They indicate, to all appearances, the passage or stay, long or short, of workmen belonging to the same class, but who were not natives. Foundries are, in fact, always found in isolated spots, but no traces of human habitations are seen. It is true that habitations may disappear, wooden houses crumble into dust, and the very stones become, in the course of time, dispersed and used elsewhere. There is, at any rate, one product of human industry which never disappears, and attests the presence of man during the most ancient times; that is the baked clay and especially broken pottery. Its tenacity is such, that on closely comparing the soil with some of the fragments, it is often easy to determine the place and size of cities which have disappeared several centuries ago. The neolithic foundries are never surrounded by such ruins.

There are but few lacustrial habitations where the metals were wrought, but here the natives might have been taught by travelers. The initiation seems, in fact, probable, from the existence of certain inhabited spots, which are called *stations*. Those which are known are not very extensive; in most cases they are on a line with rivers, as may be seen, for example, on the banks of the Saone between Chalons and Tournus; still there are some isolated ones. The most important of them all is that of Saint-Pierre-en-Chastre in the forest of Compiégne. It is situated on the calcareous plateau in the swampy plains of Vieux-Moulin. It was dug by M. Viollet-le-Duc in 1860, and yielded, among other things, more than five hundred bronzes, which are indistinctly attributed to Gaelic armies. Since then, science having made some progress, they have found that it is necessary to distinguish the objects of stone, bronze, or iron obtained in that locality; that all was anterior to the time of Caesar; that there were few arms; that the quality of bronze was identical to that of the other layers of that age throughout Europe. On close examination, comparisons showed that the station of Saint-Pierre had probably existed for several centuries, and that it had witnessed if not the first appearance of bronze in that country, at least the epoch of that metal, and the commencement of the iron age.

But the interest in the stations is, in part, lost in that of the *trésors*, as these seem to demonstrate the reality of the traveling founders; the idea merely being suggested by the foundries. The most important were found in the Alps on the neck of the mountains, some near Moulins and Gannat, two in Meusth, and one near Sarrelouis; there are altogether twenty-nine in France, comprising upwards of 1350 pieces.

These treasures are composed of new objects, never having been used; sometimes several are joined together having been cast in the same mould.

They are found in small cavities expressly dug, where they seem to have been hidden for a short time by their possessors. These treasures, those of the Alps at least, are often found on high ground, not far from roads, frequented by travelers going from one country to another. There are no signs of a foundry in the vicinity, or even of a station, the spots where they were found are deserts. Is there anything to be found in these temporary deposits

besides objects of traffic? Were they not hidden by the same men who, in the valleys, recast the inferior products of their own industry? If all this leads us to believe that such is the origin of the treasures, there would only have to be determined the direction in which these workmen went, to know whether they came from Italy to France, or vice-versa. It will directly be seen that this difficult problem is no longer insoluble to-day.

The treasure of Reallon, which is now in the museum of Saint Germain, was found in that village not far from Embrun 3880 meters high. "This road, anciently frequented by foot-travelers, leads from Saint Bonnet to Embrun, by Gociere." The treasure of Beauvièars was found by a farmer. This village of the arrondissement of Die is situated on an ancient passage of the mountains, on the peak of Calre, on the road to Luc. There were many other valuables which had been stowed away on the upper banks of rivers, as well as on the plains.

IV.

We must now speak of the industries of the bronze age of which the several strata compared with each other have revealed the existence, nature, processes and relative epochs; among them there were some indigenous. Undoubtedly the men of those ancient times must have built their own houses, which were made of wood, after the time they left the caves. Those they erected on solid ground have disappeared without leaving any traces behind; and if the houses of the lakes have been destroyed, at least the piles upon which they were built still remain. Those of the epochs anterior to metal, were nearer the banks and did not project so far out of the water. The others were built beyond the first, and in Savoy, have a greater jutting out, by which they can easily be recognized. The pieces of wood resting on the piles and forming the flooring, were fastened together by means of tenons and mortises; which shows clearly that they could with hatchets and chisels of stone, cut and shape large pieces of wood. Planks were made by splitting the trunks of trees; the stone saws are only several inches long, while those of bronze are not a foot; they could only be used on light work. Of these several specimens have been extracted from the lakes of Savoy, such as spoons, tool handles, spindle shanks, sabots, a porringer, and part of a bucket.

The great number of bobbins of baked clay which are called by the Italians *fusaioles*, indicate that the custom of spinning and weaving was then extant; there were many discussions as to the use of those small cones bored through their *axis*, but there is now no more doubt, since a complete spindle was found in the lake of Bourget. We have ourselves seen pieces of wood worn out in the holes of many bobbins, found in Troy by Dr. Schleimann.

These very things are still used throughout the Middle and West of Europe. They could obtain very delicate threads with these spindles of wood and clay, as is evident from the smallness of the eye of several bronze needles. The finest textures have been destroyed under water as well as under ground, but a few specimens of the coarser textures, meshes of nets, thread, cord, and bundles of beaten flax, have been preserved in the mud of the palafittes of Bourget. The flax then used had small leaves, and differed from the kind now cultivated. To the weaving we may add the fabrication of baskets of rushes, reeds and osier, and the making of fishermen's snares, and the large hurdles which were used to fortify the walls of houses in supporting the roof.

The local industry which has left the most traces in the strata of bronze, except the treasures and foundries, is the moulding of argil. We have already noticed that the potteries of the periods of stone were not baked, but merely dried in the sun. The art of baking was introduced during the age of polished stone, and continued to be improved during the entire age of bronze. Still the most ancient vases of that period were badly baked, very often burnt on one side and raw on the other; it would seem that these potteries were cooked in the open fire and not under a reverberated furnace, which however was the case. The dishes and plates showed few signs of the fire. It was only towards the end of the bronze age when iron was already beginning to supplant it, that the potter's wheel was used. As simple as was this revolving machine, it afforded

certain facilities of fabrication which were formerly unknown. The progress seems to have been made only after the appearance of iron. The various kinds of vases fabricated by processes so elementary were astonishing. Some were used for carrying water, others for preserving and cooking food. There were also some drinking vases, among which are the rhytons, and lamps in imitation of the old Greek and Roman lamps, rings of clay used as rests for small-cased vases and peforated cheese molds as in our own day, which shows that men in olden times were fond of the product of the dairy.

With regard to the ornamentation of pottery, it has received special attention from scientists, for it has afforded, during the bronze age, transformations useful in chronology, which are found on contemporaneous bronzes. The rough pottery of the stone age was ornamented by straight lines engraved thereon with zig-zags more or less irregular. In course of time these lines became more regular, and are drawn parallel by means of burins with several points, consequently the figures are more accurately made. The use of concentric rings may be noticed throughout Europe during the bronze epochs. The plain cross, the multiple and four pointed cross, the encircled cross in shape of a wheel, stars and triangles appear regularly in successive years.

The figures are no longer merely engraved with pointed instruments, they are also impressed with stamps of metal, clay, or stone. The Swastika (a species of cross with curved arms) and the meandre which is made up of a succession of swastikas, are to be met with especially during the period of transition from bronze to iron. During the first iron age, and further on in historic times, this figure was popular with the people of the Aryan race, and appeared in the west after the bronze ear. It was about this time that the potters began to paint certain vases with red or yellow ochre or with that black which afterwards became peculiar to Grecian ceramics. Lastly, the inhabitants of the lacustrial dwellings used a sort of decoration which was, however, afterwards abandoned. On the dark bottom of some vases of fine clay, they fastened thin sheets of pewter cut in narrow strips, with rosin, and formed a variety of beautiful designs. Metallic ornamentation, no doubt, had its origin in the West. The industry of bronze characterizes the period now under consideration. In speaking of the foundries we made little mention of the material of the founders; so far there has been found but a small piece of mineral brass, and nowhere in Europe has a furnace or any instrument for extracting ore been found. We may, therefore, be justified in supposing that the metal was brought from the vicinity in its rough state, or already molded. In fact, ingots of bronze are found wherever the founders were stationed, they are in the form of small squares, or like hammers having a hole in the center to hang them up by.

We should recollect that no pure copper* is found, very little tin, whilst throughout Europe bronze is of uniform composition. The following is obtained from the analysis made by Messrs. Wibel and Fellenberg and by M. Damour; the proportion of tin is about ten per cent., but there are exceptions as in cold chisels and one or two other objects of hard bronze, which contain as much as a quarter of tin to three quarters copper. This uniformity of composition of alloy throughout Europe, proves the unity of its origin and importation, but of this further on.

Researches have brought to light besides ingots and refuse castings of metal, a number of molds made of schist, steasheist, free-stone, baked clay and bronze. Many of these have figures on two or four sides, and on some there are several figures along side of each other. The crucibles are made of earth mixed with broken quartz and often contain metal. Some have the shape of the laboratory crucible, while others are like cups with handles. All these receptacles could contain but a small quantity of metal; their form and dimensions are pretty much the same throughout Europe.

The articles, made by means so rudimentary, may be divided into three classes, viz., tools and utensils, arms and ornaments. Among the first may be included the hatchets first made similar to stone hatchets, with holes for the pur-

* It appears that in Hungary and Greece many specimens have been noted.

pose of inserting a handle which was fastened in the socket with a cord. We are able, considering the superposition of the layers in the lacustrial habitations and stations to follow these transformations, and determine their relative epochs. Scissors, knives, chisels, sickles, handles, saws, gimlets, jewelers' pincers, are the tools usually found in all the strata. We may also add razors which were first made of hard stone, then of bronze, which are finally supplanted by iron ones. These instruments were not of the same shape as they are to-day; they were semi-circular with the edge on the side of the curve. Then there were some double ones edged on both sides of their diameter, and fastened to an ornamented handle, forming together but one piece. The different razors will enable us to ascertain the relative age of the strata in which they are found.

Was the horse domesticated at the appearance of bronze? It is probable that he was tamed during the period of polished stone, and yet it is possible he may have been long before. If he was then only in a wild state, it would be difficult to explain the quantity of bones which are found in certain places of the first period of stone as in Polutré. This station which is not far from the Saone river, above Macon, contains, it is said, the skeletons of 100,000 horses, most of them young, which may have served as food for the inhabitants of the place.

Be it as it may, the bronze bits found among the piles of the lake of Briene and afterwards in France, bear witness to the fact that the horse was already subdued. The oldest of these bits are made of two moveable pieces one above the other in the center of the animal's mouth. Soon after the four pieces are movable, although each of the exterior pieces has a cross-piece through the middle, and thus forming two equal branches. This second class of bit characterize the terramares, and had been learnedly studied by Count Gozzadina. It seems that in the stone age the horse half tamed was used as food for man, that being subdued in the second period he was mounted and perhaps harnessed, and, finally, at least in Italy at the end of the bronze age he became tame enough to be guided about with a string. Arms do not form the least interesting portion of our bronze collection; they perhaps better than anything else enable us to determine the successive phases of this metal. They are found everywhere in Europe and Asia, but they should not be attributed to Gaul as has been done. The palafittes, foundries and treasures have given them their definitive place in the bronze age, and if they appear only in small quantities owing to the scarcity of the metal, they soon become so abundant as to supplant entirely the arms of stone. Later on iron is found in many places in Europe, but in small quantities and is regarded as an object of luxury. It soon after exercises in its turn an appreciable influence on bronze arms, the form and size of which are modified. Finally, bronze is entirely abandoned. The blade of the swords and poignards of the early part of the bronze age was of metal, but not the handles. Often in these primitive arms, the tongue of the blade does not go far into the handle; it is broad short and pierced with two or more holes through which the iron rivets pass. Afterwards metal handles are made, either without a guard or one in the shape of a cross. Switzerland, Denmark and Sweden have produced swords with antennæ, that is to say, with two prongs jutting out and curved at the end of the handle above the hand. The long swords, the length of which is often two feet and a half, which are to be found throughout the West, had handles made of horn, wood and bone, and resembled the iron sword which soon replaced them. In France there have been discovered 650 swords and poignards of bronze, in Switzerland 86; in Sweden 480, and are generally found throughout Europe.

The dolmens and sepulchral caves of Languedoc and Vivarais, the palafittes of the lakes of Neufchatel and Varesa, have produced arrow heads similar to those of silex which had preceded them, and used up to the transition from stone to metal; they characterize this epoch as the razor characterize the transition of bronze to iron. These small pieces of metal were flat, being fastened in the shaft with a cord.

It is during the second period of the bronze age that armor is made of metal, as helmets, shields and cuirasses; prior to this time they are made of leather and wood. This is the period

that M. de Mortillet designated by the term "Chandronnerie," the art of enlarging and shaping iron under the hammer, being added to that of molding. This method was used not only in the manufacture of armory, but also to the edging of arms and tools and of a multitude of ornamental objects.

The latter outnumbered the former, especially when metal was rare; pins are picked up by hundreds. The foundry of Larnaud has furnished 214 bracelets, the lake of Bourget more than 600, and a great number have been found in the dolmens of Central Europe. The oldest are oval, the latest are round; those which date from the bronze epoch are open, but are closed as soon as the industry of iron is general. The large collar rings, called torques by the Romans, is not found until after the appearance of the latter metal; finger rings are scarce throughout Europe, but plain rings, necklaces and buckles, are everywhere found in large quantities; there are besides these many other ornaments or amulets, such as ear-rings, fillets, &c., which evidently have a symbolic character. Let us here note that these symbolic figures are about the only signs of any religion during the bronze epoch. We may add that they are not indigenous, but are doubtless derived from Asia, as also the cithern which is made of hollow reeds with nine or twelve rings fastened at the end of a stalk of wood. There are several in existence, two of which were found in France, three in the lake of Bourget, the others at Christiana, at Wladimir and Yavorlan. These citherns are not like those of Egypt, but like those of the priests of Buddha, who themselves hold them of an ancient Aryan tradition.

V.

We have just placed before our readers the general conditions of the problem relative to the origin of metallurgy in Europe.

From the facts which have been briefly stated, but may be found enumerated and more fully described in M. Chanter's great work, and especially after seeing the objects themselves in our museums, they will satisfy themselves that the problem is henceforth well sustained, that the method of proceeding is determined, that the researches of primitive bronze and the scrupulous examinations of the strata in which it is found are the principal if not the only means to arrive at a solution, and that finally the accumulated works of many learned men throughout Europe have already given to science a large and solid foundation. This immense work which we have condensed in a few pages was begun about forty years ago, but has been generally known only within the last twenty years.

Europe has not yet exhausted itself, still we feel that the origin of metallurgy must be sought for outside of its frontiers. When warriors will give a little respite to science, the East of Europe and Asia will become the scene of scientific discoveries; in fact, the first appearance of the metals must be sought for in the Southeastern portion of Asia. Still to be certain of the fact, we should, by investigations analogous to those made in Europe for the last twenty years, to a certain extent trace the routes which the industry and commerce of the metals have pursued. These routes, at least with regard to bronze, will converge no doubt towards one point. If Central India and Tartary had simultaneously furnished this metal, we would see in all the collections of Europe two different types and, probably, two different alloys in objects of the same kind; but the converse is true. Except the local differences arising in different ages, the products are the same throughout the West, from Sicily to the Northernmost of Sweden and Russia. The composition of bronze obtained from a number of analyses in which the approximation was to a ten-thousandth part, is the same everywhere; the scientific processes are identical. The three successive epochs of the bronze age is everywhere perceived; first, wherein it is seldom found amid a people occupied in polishing stone; second, wherein metal has definitively replaced the latter in certain usages when decidedly superior, and lastly, wherein bronze concurs with a new metal, iron, which eventually supplants it. Such a uniformity at a time when there were no roads and no protection, when the races which inhabited Europe had not yet mingled and experienced their respective wants, and

had their own special trades; in fine, the absence of tin in Europe except in Cornouailles, as well as native copper, are sufficient reasons to lead us to believe in the foreign origin of metallurgy.

To arrive at a starting point we could at present proceed by elimination and show that neither Northern Asia, Caucasia, Tartary nor Egypt could furnish bronze to ancient Europe. In narrowing the circle we would be led, as many scientists have been, to look upon Asia Minor as the country through which bronze was carried, and India as the place of its origin. But India itself is large; from Cape Comorin to the Himalayas the distance is about that from Marseilles to Petersburg. Moreover, India does not produce its own bronze, it imports it. This method, however, which is not very scientific, and which has led many men astray, merits some consideration; bronze, which is a composition difficult to produce, must have originated in a country where the elements are to be found; India does not produce tin. We should regard the peninsula of Malacca and Banca, which are even to-day the two great centers for the production of this metal, as the birth-place of bronze; these facts then are the result of the system of elimination. We do not mean to say one would be led into error, but at most would only propound a probable hypothesis. The learned scientists have attempted to solve the problem by reference to texts; unfortunately the most ancient texts are of recent date, considering epochs of such antiquity. Moreover the authors of these texts, whose individuality is a matter of doubt, were not well informed, since none of them had any idea of the three successive ages of humanity. In vain did M. de Rougemont, in 1863, with only the aid of texts, pretend to have solved in his cabinet the problem, for a solution of which scientists have sounded lakes, turned over the sods of the field, and dug into the mountains. This learned man, for whom the book of Genesis was a sufficient authority in metallurgy, designates Phoenicia as the country from whence European bronze was obtained. But there are not mines either of tin or copper in Phoenicia; the nearest copper was to be had in the isle of Cyprus which after all was not Phoenician; besides, these were never producers, but only merchants. It would be impossible to show any Phoenician bronze anterior to iron. We will here add that the emblematical figures of Europe are foreign to Phoenicia, and that the author of the fourth chapter of Genesis had but vague notions regarding the origin of metals. There is then no other method to follow but the observation and comparison of facts. If the facts just enumerated prove the foreign and unique origin of bronze industry, the local differences are liable to three divisions in Europe; the Ural, Danubian and Mediterranean, and these may be subdivided into provinces. In noting the successive epochs indicated by the superposition of the layers of the palafittes and stations, we can determine the relative state of this industry in the different provinces of each group with each of the three epochs of the bronze age. The nature of the objects associated in the layers show the successive phases through which this industry passed. Now the first bronzes sold in exchange for amber, furs, leather and other products, to the polishers of stone, were bijoux and amulets. We are able, by comparison, to follow the march of the commerce of jewelry from country to country in each province. We next find utensils and arms, and, lastly, appears the era of metal beating, that is, the hammering of bronze, following the simple fusion, and thereby undergoing a complete change.

These three series of observations, founded on the thousand objects in the public and private libraries, have shown that if the Ural group which borders on Asia is set aside, the provinces of the Danubian group received bronze from regions near or below the Danube, while Savoy, France and a part of Switzerland received theirs from Italy across the Alps. The waters of the Danube spread as far as the lakes of Eastern Switzerland, and it is to this river we are indebted for the bronze objects found in the palafittes of Zurich, while those of Savoy were borne by Italian waters. The bronze works of Germany, Denmark and Sweden, and, to a certain extent, those of England and Ireland belong to the Danubian Industry.

The Italian industry fills the basin of

the Rhone, and extended on one side as far as Savoy, on the other to Cevennes, then proceeded to the North of France, its influence being felt as far as Great Britain.

Now how was this propagation of metallurgy effected? The foundries and treasures answer the question, imperfectly however. The earliest disclose foreign workmen who established their workshop in open fields, not in populated cities, but in their vicinity. Not having any permanent homes, they wandered from place to place and would here and there melt old articles and mould new ones, any deficiencies being supplied from ingots or bars of bronze they carried about with them; their treasures much resembling the parcels and bundles of nomadic merchants. How can we account for the appearance of those found at the top of mountains where there are no habitations? But the findings indicate that these unfortunate men did not return and that they were a prey to violence or misery in other quarters. And why have these very foundries preserved the molds and crucibles, the ingots and broken objects which were to be recast? Why should these workmen have left these articles behind them? Or, rather, have they not been the victims of hatred or cupidity? Herodotus says, that there was in his time a sort of corporation or class composed of nomadic founders who came from Asia. During the whole of the middle ages, these strangers differing from the men of the West, frequented our cities and towns. Their nomadic mode of life, their unknown tongue, their strange customs and religion which seemed to be paganism, were the cause of their being hated and ridiculed, although their services were much needed. They were murdered without mercy. Modern industry has almost banished them from the most civilized countries; but they overrun the East, the Middle and North of Europe, without counting the whole of Asia; they come like the men of the bronze foundries, to remain a few days in the fields near the cities. They are known by different names in different countries; tsiganes in Hungary, zingari in Italy, bohemians in France, gyphtes or Egyptians in Greece, gypsies in England, and gitanas in Spain. They are not united together, but are members of a corporation dependant upon a chief. It is from this chief residing at Pesth that they receive the metal, and he himself receives it from another who lives at Temesvar, but whence does he obtain it? It is probable that the similarity of the events of the bronze age and the customs of modern pewterers, will enable the scientists to discover the course of ancient metallurgy. The route of commerce is not much changed in countries where the inventions of our day have not yet penetrated. The processes were perpetuated; in the East the same tribes furnished men in the same business. Now it is a fact that the tsiganes belong to India; we know from another source that there were no castes in the time of Veda, but there were then trades among which that of founder had important place. But are these founders of Aryan race? Did they belong to that part of the conquering nation which, in its march to the Southest had not yet reached the valley of the Ganges, nor gone beyond the Saraswati? It is easily seen that problems arise and multiply, and how necessary it now is to pursue, outside of Pesth (the last place of the anthropological congress), the searching which has been going on in the West for the last quarter of a century.

The point of departure from the Italian current is not any better known. Discoveries have shown that the Rhodanian industry comes from Italy, and that Italy made more progress than the countries farther North; but the working of bronze is not any more original in Italy than it is in France or Savoy. From which side did the founders gain access to Italy? Did they come from Greece or from the islands? And when it will have been shown that they came from Greece and that Greece preceded Italy in civilization during the bronze epoch, it will be necessary to show from whence Greece received her bronze. Did she obtain it from Asia Minor, Cyprus or Egypt, or from some other country? From the moment we disregard the Adriatic, the problem is unsolved, as the countries beyond this sea have not yet been searched. The discoveries made at Santorin by M. Fouque and the French school, and especially the great researches of Dr. Schliemann, at Troy, and Mycenæ, throw

a ray of light on our subject, but do not yet entirely solve our problem. And this will not be until new discoveries shall be made in many places in the Grecian peninsula, in the islands, and over the far-spreading surface of Asia.

In these countries there will needs be found the commercial equivalent given by the men of the West in exchange for bronze brought by the Eastern men. These objects of barter will be found to consist principally of yellow amber, a precious substance which remains intact in the earth as well as in the sepulchres. The comparative study of religion will furnish to science a helping hand, for we know that the symbolical figures of certain bronzes found in the west belong to the Aryan race and come from Central Asia or India, such are the swastika, the cross, the wheel, the crescent, the disc, the stars and numbers. These symbols, plainly characterized, will be like so many stakes in all places where they shall be found, and these stakes marked on the chart of the world, will indicate the metallurgic paths. Philology already gives us a little information, but perhaps we should not depend on it too much, for the names given to the metals by the Aryans of the West do not always have the same signification they do in the East; but, as in India for instance, the names designating the same metal, same industrial product, same figure are always numerous and significative, they will enable us by comparisons, which will complete or clear up those derived from science, and thus will the study of texts, which has been so abused, become useful. Be it as it may, scientists admit at present that the courses of metallurgy in Europe--that of the Danube and that of Italy and the Rhone start from the European continent and tend to converge towards a central point of Asia which has not, however, yet been determined, but they also admit that the epoch when bronze was introduced in Europe among the people of the neolithic period is yet at the state of the geological period, and cannot be included in any chronology. Will a real date ever be determined upon, or at least an approximate one? We doubt it, but at least hope so.

THE CO-EFFICIENT OF FRICTION FROM EXPERIMENTS ON RAILWAY BRAKES.*

By Captain DOUGLAS GALTON, C.B., F.R.S., D.C.L.

From "Journal of the Society of Arts."

The author of this paper has been recently engaged in making some experiments upon the co-efficient of friction when the surfaces in contact move at high velocities, in connection with the action of brakes in use on railways; and the results which have been arrived at appear to present some interesting features in respect of the laws which govern the co-efficient of friction.

These experiments form the first installment of a series which it is intended to make, to ascertain, 1st, the actual pressure which it is necessary to exert on the wheels of a train to produce a maximum retardation at different velocities; 2nd, the actual pressure exerted on the wheels in the several forms of continuous brakes now in use; 3rd, the time required to bring the brake-blocks into operation in different parts of a train in the several forms of continuous brakes; 4th, the retarding power of the different kinds of continuous brakes now in use on trains under similar conditions of equal weight and running at the same speed.

This paper includes the first series of experiments only.

The author was enabled to make this series through the courtesy of the London, Brighton, and South Coast Railway Company, and of their locomotive superintendent, Mr. Stroudley, who provided a van and other facilities for making the experiments; and through the courtesy

* Read before Section G of the British Association. Dublin meeting.

and assistance of Mr. Westinghouse, by whom the recording apparatus was designed. The author was assisted in making the experiments, and in their reduction, by Mr. Horace Darwin.

The experiments were made on the Brighton Railway, with a special van constructed for the purpose ; it was attached to an engine, and was run at various speeds, during which time various forces were measured by self-recording dynamometers. These dynamometers were designed by Mr. Westinghouse ; Their principle is that the force to be measured acts on a piston fitting in a cylinder full of water, and the pressure of the water is measured by a Richards' indicator, connected by a pipe to the cylinder; thus, as the drum revolves, diagrams are obtained, giving the force acting on the piston. The advantages of this method are obvious, as the indicator can be placed at any convenient point, and the inertia of the water tends to make the pencil keep a position corresponding to the mean force.

The piston, and what answers to the cylinder, would be better described as a ring fastened to the edge of a cylindrical box. The rod by which the thrust is to be measured is transmitted to the piston. This piston merely consists of a cast-iron disc, with a cavity in its center, in which the rounded end of the rod rests, and a projecting piece at its center on the other side acts as a guide. The ring, which takes the place of the cylinder, is of the same thickness as the piston, and in its center the piston fits. This ring is screwed to the edge of a cylindrical box, to which the ring with the piston thus forms a cover. The piston fits so as to slide easily, with but little friction, and is made water-tight by placing a disc of india-rubber under it, which is fastened to the center of the piston by a brass collar, and has its edges clamped in between the ring and the edge of the cylindrical box. Thus we have a perfectly water-tight piston, which will move with very little friction, and as its movement is very small, the disturbing effect of the india-rubber at its edge may be neglected; thus the indicator will register the forces acting on the piston by means of the pressure of the water. The pipe leading to the indicator is screwed into the socket. We will neglect the valve for the present, and explain its use a little further on. Suppose the whole apparatus to be filled with water, and that a force were applied to the piston by the rod, it would force some of the water out of the vessel through the opening into the indicator cylinder; the area of the indicator piston is half a square inch, and its maximum range .8 of an inch, therefore the quantity of water required to make a maximum movement of the pencil is 0.4 cubic inches, and as the area of the piston is 30 square inches, its movement would only be 0.013, or $\frac{1}{75}$ inch, which is such a small movement that the india-rubber will introduce no appreciable error. Now, if the indicator piston did not leak, and if it were possible to keep exactly the right quantity of water in the apparatus, nothing more would be required to make it work properly, but as this is evidently impossible, the supply valve becomes necessary. A small pipe, leading from an accumulator loaded to a greater pressure than can ever arise in the vessel, is screwed into the socket; the excess of pressure on the outer side tends to close the valve ; there is also a spring which forces the valve on to its seat. This valve is seated with india-rubber, and is made perfectly water-tight. The spindle passes up so as very nearly to touch the brass collar on the underside of the piston. Suppose the whole apparatus to be filled with water when there is no force acting on the piston ; then if a force is applied, this will move the piston downwards, so as to send some water into the indicator, and raise the pencil, and will also open the valve, and, as the pressure in the accumulator is in excess of that in the vessel, the water will enter, and go on entering till the piston is raised and no longer opens the valve. Now, if the force on the piston be removed, the indicator spring will force a quantity of water less than 0.4 cubic inches back into the vessel and raise the piston less than $\frac{1}{75}$ inch, and thus the piston can only move $\frac{1}{75}$ inch above the position in which it touched the valve. Again, if we suppose a smaller force to be applied to the piston, it will not be pressed down so far, and will not open the valve unless sufficient leakage has meantime

taken place to allow the piston to come down through its full distance; thus the valve always keeps the right quantity of water in the apparatus to make it work properly, by occasionally opening and letting in enough water to make up for leakage.

A special brake van was built by the London, Brighton, and South Coast Railway Company for these experiments, to which the Westinghouse automatic brake was applied, with four dynamometers, like the one described, attached to it. Nos. 1 and 2 measured the retarding force which the friction of the brake-blocks exert on the wheels; No. 3, the force with which the blocks press against the wheels; No. 4, the force required to drag the van. The arrangement of the levers for applying the brake is not the same as that used on the ordinary rolling stock of the Brighton Railway, but has been slightly modified by Mr. Westinghouse in order to make the pressure equal on both sides of the wheels, and to provide for the application of the dynamometers. Into the cylinder belonging to the Westinghouse brake apparatus the compressed air flows from the reservoir when the brake is applied, and forces the two pistons apart, thus moving the two rods outwards, and by means of their levers, pressing the brake-blocks against the wheels. It is evident that the pressure must be equal on each side of the wheels, and that the pressure on the dynamometer No. 3 must be equal to the thrust on the rod, and hence proportional to the pressure on the wheels. The lever pivoted at its center will evidently tend to turn with a moment equal to the retarding moment exerted by the friction of the brake-blocks on the wheels; and hence the dynamometers Nos. 1 and 2 will register forces proportional to this moment. The brake could be applied to all the wheels of the van, but during the experiments it was only applied to the pair of wheels to the levers of which the dynamometers were attached. Dynamometer No. 4 is connected to a draw bar by a lever, and thus registers the force required to draw the van.

A self-recording speed indicator was used, designed by Mr. Westinghouse. This instrument has been repeatedly tested, and was used at the brake trials on the North British Railway, and on the German State Railway. It consists of a small dynamometer made on the same principle as that just described; it measures the centrifugal force of two weights, which are made to revolve by a strap from a pulley on a shaft driven by friction gear from the pair of wheels to which the brake was applied; a Richards' indicator being used, as in the other dynamometers. Thus, as the centrifugal force varies as the square of the velocity, the speed is got by taking the square root of the ordinates at any point. There is also a Bourdon gauge attached to the above small dynamometer, with the face divided in such a way that the hand shows the speed in miles per hour.

These diagrams thus show the speed of the pair of wheels to which the brake was applied, and therefore the velocity of the train at the moment of applying the brake and subsequently—provided there is no slipping. Any variation in the speed diagram is due to the wheels slipping, and shows to what extent and in what way the brake stops the wheel.

Two of Mr. Stroudley's indicators were fixed side by side in the van; one attached to the axle belonging to the braked wheels; the other to the axle which was running free. The difference of these indicators showed if slipping took place.

Speed indicators were also attached to the van; but these do not register automatically.

The distribution of the weight of the van between the two pairs of wheels was obtained, as well as the weight of the wheels and axles themselves.

In order to ascertain the weight thrown on the braked wheels during the progress of the experiment, a dynamometer fitted to the springs of the van showed the weight at every moment carried on the unbraked wheels, from which information it was easy to deduce the weight on the braked wheels.

The indicators are all placed on a table in the center of the van, and the drums are made to revolve by the cords being wound up on pulleys on the shaft. This shaft is turned at a uniform rate by a water-clock. This clock merely consists of a plunger sliding in a cylinder through a water-tight packing, and loaded with a heavy weight; it is wound up

by connecting it with the accumulator, and at the beginning of each experiment a small cock is opened, which allows the water to run out and the weight to fall, which thus turns the indicator down, and at an ascertained uniform speed. Thus the ordinates of the diagrams taken from these indicators show the various forces, and the abscissæ the distance moved through by the van.

In these experiments the tyres were of steel, and the brake-blocks of cast iron.

The apparatus was designed by Mr. Westinghouse, and constructed under his supervision by the Brighton Railway Co., through whose assistance these experiments were carried into effect.

The effect of applying the brake to the wheels is two-fold. So long as the wheels to which brakes are applied continue to revolve at the rate of rotation due to the forward movement of the train, the effect of the blocks is to create retardation by the friction between the block and the wheel; but when the pressure applied to the block causes the friction to exceed the adhesion between the wheels and rail, the rotation of the wheels is arrested, and the wheel becomes fixed and slides on the rail, being held in its fixed position by the brake-blocks.

Therefore the experiments give the co-efficient of friction:—

1. Between the brake-blocks and the wheel, which is equal to

$$\frac{\text{the tangential force}}{\text{the pressure applied.}}$$

2. Between the wheel and the rail, which is the

$$\frac{\text{friction of the brake-blocks}}{\text{weight upon the wheels.}}$$

They moreover afford a measure of the adhesion between the wheel and the rail.

It has been generally stated that there is no difference in the co-efficient of friction observed in the case of bodies at rest, *i.e.*, in a condition of static friction, and the co-efficient of friction in the case of moving bodies, *i.e.*, in a condition of kinetic friction; but Mr. Fleeming Jenkin, in his paper read before the Royal Society, in April, 1877, upon the friction between surfaces moving at very low speeds, alludes to the fact that in cases where a difference in the co-efficient of friction is observed between static and kinetic friction, the static friction exceeds the kinetic.

Coulomb also points out his experiments that in the case of static friction the co-efficient of friction increased with the time during which the bodies had been at rest.

The experiments of Coulomb, Rennie, Morin, and Jenkin, were made with bodies moving at comparatively low velocities.

The table (p. 523) shows the mean results obtained from a large number of the experiments made with the apparatus above described, upon the action between the cast-iron brake-blocks and the wheels fitted with steel tyres.

A limited number of experiments were made with wrought iron blocks upon the steel tyre, a mean of which gave the following result:—

Average.		Co-efficient of Friction between Wrought Iron blocks on Wheels.			
Miles per Hour.	Feet per Second.	At Commencement of Experiment to 3 Seconds.	At from 5 to 7 Seconds.	At 12 to 16 Seconds.	At 24 to 25 Seconds.
48	..	.110	..	..	..
31	..	.129	.11	.099	..
18	..	.170	..	..	..

The following table shows the result obtained by the sliding of the wheel on the rail, that is, a steel tyre and steel rails:

Average.		Co-efficient of Friction between Wheel on Rail, Steel on Steel.			
Miles per Hour.	Feet per Second.	At Commencement of Experiment to 3 Seconds.	At from 5 to 7 Seconds.	At 12 to 16 Seconds.	At 24 to 25 Seconds.
50	..	.04	..	..	..
45	..	.051	..	..	..
38	..	.57	.044	.044	..
25	..	.080	.074	..	..
15	..	.087	..	..	..
10	..	.110	..	..	..

Average.		Co-efficient of Friction between Cast-Iron Brake Blocks and Steel Tyres of Wheels.			
Miles per Hour.	Feet per Second.	At Commencement of experiment, *e. g.*, to Three Seconds.	At from 5 to 7 Seconds.	At 12 to 16 Seconds.	At 24 to 25 Seconds.
60	88	.062	.054	.048	.043
55	..	..	..	..	..
50	73	.100	.070	.056	..
45	65	.125	..	..	..
40	58	.134	.100	.080	..
30	43	.184	.111	.098	..
20	29	.205	.175	.128	.070
10	14	.320	.209	..	..
Under 5	7	.360	..	..	..
Fleeming Jenkin, Steel on steel dry........	.0002 to.0086	.351 mean .365 max.	..	..	..
Morin, Iron on iron.....	..	.44	..	..	..
Rennie, At pressure of 1.6 cwt. per square inch wrought iron on cast iron........	..	.275	..	..	..
" —Steel on cast-iron.	..	.400	..	..	..

The general results of these tables show that the co-efficient of friction between moving surfaces varies inversely in a ratio dependent upon the velocity at which the surfaces are moving past each other; probably the equation would be of the form of $\frac{a}{b+v}$.

The co-efficient of friction, moreover, at these velocities becomes smaller also after the bodies have been in contact for a short time. That is to say, the longer the time the surfaces are in contact, the smaller apparently does the co-efficient of friction become. This result appears more marked in the case of cast-iron blocks than of the wheel sliding on the rail, at all events for the first thirty seconds of the contact, the arrangement not admitting of the experiments being carried on for a longer time. This effect, however, does not appear to be unnatural, as the friction develops heat, and the consequent expansion tends to close up the pores, and to make the heated surface a more united surface than the colder surface. Besides which, it is probable that in the act of rubbing, small patches may be detached, which may act as rollers between the surfaces.

It will also be observed that the co-efficient of friction between the cast-iron block and the steel tyre is much larger than that between the steel tyre of the wheel and the rails, which are also generally of steel.

As has been above mentioned, the sliding of the wheel on the rail takes place when the friction of the brake-blocks is greater than the adhesion between the wheel and the rail, which is due to the weight upon the wheel. This was found to amount generally to about 24 to 28 per cent. of the weight.

The influence which these results have upon brakes for railway trains may be briefly summarized as follows:—

1. The application of brakes to the wheels, when skidding is not produced, does not appear to retard the rapidity of rotation of the wheels.

2. When the rotation of the wheels falls below that due to the speed at which the train is moving, skidding appears to follow immediately.

3. The resistance which results from the application of brakes without skidding is greater than that caused by skidded wheels.

4. The pressure required to skid the wheels is much higher than that required to hold them skidded; and appears to bear a relation to the weight on the wheels themselves, as well as to their adhesion and velocity.

In order to produce a given result at different velocities, the pressure applied to the brake-blocks must vary in the proportion shown by the co-efficient of friction.

Thus at 50 miles an hour the pressure required to make one pair of wheels

slide on the rail was nearly 27,000 lbs., whilst at 20 miles an hour a pressure of about 10,300 lbs. was found sufficient to obtain the same result.

The strain on the draw-bar showed that the retarding force or the tangential strain between the brake-blocks and the wheels followed very nearly the same law of variation. This is to say, in order to produce a degree of friction on the wheel at 50 miles an hour which shall exert a retarding force on the train equal to that at 20 miles an hour, the pressure applied to the brake-blocks at 50 miles an hour must be nearly two and a half times as great as that required at 20 miles an hour, and a still greater pressure is required for higher velocities.

Therefore, whilst a comparatively low pressure would make the wheels slide at low velocities, it was difficult to obtain any sufficient pressure to make the wheel slide at velocities over 60 miles an hour.

The figures given in the above tables must at present be accepted as only provisional, until an accurate mean has been obtained from the diagrams, which are not yet all worked out. But it may be assumed as an axiom that for high velocities a brake is of comparatively small value unless it can bring to bear a high pressure upon the surface of the tyre almost instantaneously, and it should be so constructed that the pressure can be reduced in proportion as the speed of the train is reduced, so as to avoid the sliding of the wheels on the rails.

EXPERIMENTS ON THE HEIGHTS, &C., OF JETS FROM THE HYDRANTS OF THE KINGSTON WATERWORKS, JAMAICA.

By FELIX TARGET, Assoc. Inst. C. E.

From Proceedings of the Institution of Civil Engineers.

Numerous experiments were made with nozzles of various sizes and different lengths of hose, attached to hydrants on the street mains, which mains were of varying diameter. The accompanyiny table (see p. 525) gives the results of some of the experiments, those cases best suited for comparison having been selected. The height of the jet was measured from the outlet at the nozzle to the upper part of the curved spray described by the jet. The copper hand-pipe, 4 feet in length, was always held breast-high, with the nozzle 5 feet to 6 feet off the ground. The leathern hose was of the kind ordinarily used in London, $2\frac{1}{2}$ inches in diameter and in lengths of 40 feet. The hydrants and stamp pipes were Bateman and Moore's. The mains were nearly new, and were coated inside with Dr. Angus Smith's preparation. The draught of water for the town for twenty-four hours was equal to 1,266,600 gallons, the maximum per hour being 93,000 gallons. During the time the experiments were carried on the draught was 45,000 gallons per hour, which is the average night consumption. The experiments were made in the early morning in a still atmosphere.

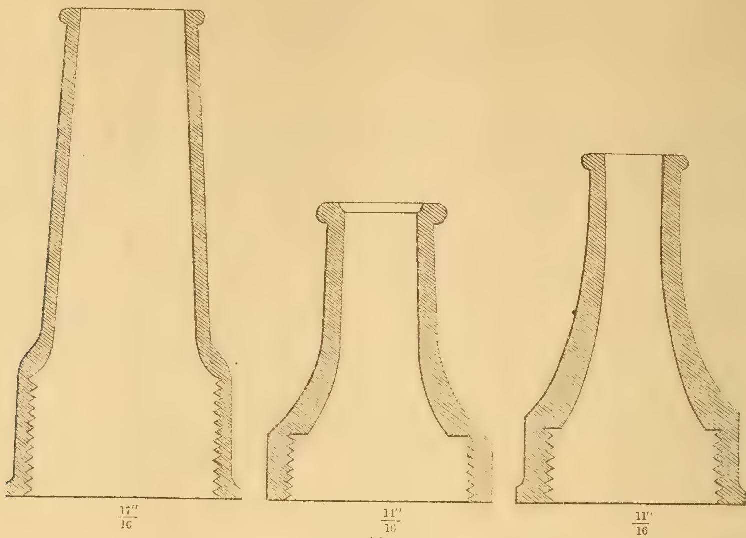
The accompanying figures show the forms of three of the nozzles. Up to the highest pressures the $\frac{17}{16}$ inch nozzle threw a much more compact jet, with less spray, than either the $\frac{14}{16}$ inch or the $\frac{11}{16}$ inch nozzle, the smaller of which occasioned the greatest spray. The heights are only correct within a few inches, as the jets slightly varied during the time of the experiments, notwithstanding that the pressure gauge, which was used to ascertain the head of water, remained nearly steady.

From these experiments it is difficult to arrive at any correct law, or formula, for calculating both the height and the delivery of water from jets in a town. It is evident, however, that with high pressures, although the 2-inch mains are large enough to furnish an ample and constant supply to forty houses, each drawing from 200 gallons to 500 gallons per day, yet they are undoubtedly too small for fire purposes without the aid of a fire engine.

The four inch mains gave results

RESULTS OF EXPERIMENTS ON THE HEIGHTS OF JETS, DELIVERY OF WATER, ETC., AT THE KINGSTON WATERWORKS, JAMAICA.

1 Number of experiment.	2 Size of Nozzle in Inches.	3 Height of Jet in Feet.	4 Number of Gal. p. Min.	5 Head in feet at Hydrant.	6 Length of Main in Yards.
No. 1. — With one length of hose. ...	$\frac{17}{16}$	20½	92	53½	1,083 of 21-inch. + 50 of 4-inch.
	$\frac{14}{16}$	34½	55	..	
Ditto, with three lengths of hose....	$\frac{17}{16}$	18	..	..	
	$\frac{14}{16}$	29½	..	..	
No. 4. — With one length of hose.....	$\frac{17}{16}$	38	122	92	1,585 of 21-inch. + 133 of 12-inch.
	$\frac{14}{16}$	44½	73	..	
	$\frac{11}{16}$	44	66	..	
No. 5. — With one length of hose....	$\frac{17}{16}$	9	66	92	1,585 of 21-inch. + 183 of 12-inch. + 66 of 2-inch.
	$\frac{14}{16}$	25	55	..	
	$\frac{11}{16}$	27	47	..	
No. 6. — With one length of hose....	$\frac{17}{16}$	55	138	122.4	1,585 of 21-inch. + 600 of 12-inch. + 116 of 4-inch.
	$\frac{14}{16}$	68	94	..	
	$\frac{11}{16}$	77	73	..	
Ditto, with three lengths of hose....	$\frac{17}{16}$	48½	..	..	
	$\frac{14}{16}$	62	..	..	
	$\frac{11}{16}$	66	..	..	
Ditto, with six lengths of hose...	$\frac{17}{16}$	26½	100	..	
	$\frac{14}{16}$	51½	82	..	
	$\frac{11}{16}$	62	69	..	
No. 7. — With one length of hose.....	$\frac{17}{16}$	7	52	122.4	1,585 of 21-inch. + 600 of 12-inch. + 166 of 4-inch. + 20 of 2-inch.
	$\frac{14}{16}$	24	47	..	
	$\frac{11}{16}$	27	..	..	
No. 9. — With one length of hose.....	$\frac{17}{16}$	11½	60	106	1,585 of 21-inch. + 266 of 12-inch. + 60 of 4-inch. + 100 of 2-inch.
	$\frac{14}{16}$	32	47	..	
	$\frac{11}{16}$	32	..	..	
Ditto, with three lengths of hose...	$\frac{17}{16}$	12	..	..	
	$\frac{14}{16}$	29	..	..	
	$\frac{11}{16}$	32	..	..	
No. 13.—With one length of hose....	$\frac{17}{16}$	58	136	156	1,585 of 21-inch. + 1,266 of 12-in. + 116 of 4-inch.
	$\frac{14}{16}$	85	130	..	
	$\frac{11}{16}$	84	94	..	
Ditto, with three lengths of hose....	$\frac{17}{16}$	48	180	..	
	$\frac{14}{16}$	64	132	..	
	$\frac{11}{16}$	62	94	..	
Ditto, with five lengths of hose....	$\frac{17}{16}$	41	143	..	
	$\frac{14}{16}$	55	132	..	
	$\frac{11}{16}$	62	103	..	
No. 14.—With one length of hose.....	$\frac{17}{16}$	15½	73	154¾	1,585 of 21-inch. + 1,266 of 12-in. + 70 of 4-inch. + 87 of 2-inch.
	$\frac{14}{16}$	28	73	..	
	$\frac{11}{16}$	35	60	..	
Ditto, with three lengths of hose....	$\frac{17}{16}$	18½	78	..	
	$\frac{14}{16}$	29	68	..	
	$\frac{11}{16}$	46	66	..	
Ditto, with five lengths of hose....	$\frac{17}{16}$	14½	70	..	
	$\frac{14}{16}$	26	66	..	
	$\frac{11}{16}$	35½	55	..	
No. 20.—No hose. Direct from 2-inch main.............	$\frac{17}{16}$	10½	64	157	1,585 of 21-inch. + 1,050 of 12-in. + 125 of 4-inch. + 111 of 2-inch.
	$\frac{14}{16}$	22½	55	..	
	$\frac{11}{16}$	37	60	..	



Scale ½ full size.

nearly equal to the 12 inch mains with an effective head of 155 feet. Taking height and quantity into consideration the $\frac{14}{16}$ inch nozzle with the higher pressures appeared to give the best results.

THE PREVENTION OF RAILWAY AND STEAMSHIP ACCIDENTS.*

By Professor OSBORNE REYNOLDS.

From "Iron."

The past twelve months has been no ordinary period. Political events of the very first magnitude have followed each other in rapid succession, and the mechanical events have been of such vast importance and interest that they have successfully competed with their political rivals, and have secured for themselves no ordinary amount of public interest.

Railway and steamship disasters of this year are calculated to impress upon us that, take what precautions we may, we cannot do away with accidents altogether. We must face the risk, and all we can hope to do is to reduce this risk to a minimum. It is to questions concerning this minimum risk that I wish to direct your attention.

The attention paid to the means of preventing accidents and mitigating the consequences has been steadily growing, and during the last few years it has been considerable; and this not only by engineers and those more directly concerned with the accidents, but also by the public and the Legislature. The aid of Parliament has been claimed in almost every direction, and numerous important statutes have been passed with a view to diminish risk. The object of this attention has not been solely the means of locomotion, but has embraced every species of mechanical appliance in the use of which there is risk to human life; and it is only for the purpose of reducing my subject within reasonable limits that I shall confine myself to considering some of the risks attendant upon locomotion. That rapid locomotion can never be altogether rendered free from risk will, I think, be generally

* An address before the Scientific and Mechanical Society of Manchester, England.

admitted. It is the conclusion which must be drawn from the experience we meet with in the exercise of our natural powers. For all animals, when in their natural state, do meet with accidents in consequence of their movements. And adopting the now generally accepted hypothesis as to the survival of the fittest, we at once see that the limit which exists to the size and speed of animals is only maintained in virtue of the increase of the accidents consequent on any overstepping of these limits.

From the fact that man has already gone beyond nature in the size and speed of his locomotive structures, it may be thought that when design comes in, the laws found to hold in natural selection no longer apply. Further consideration, however, will show that this is by no means the case. It is true that in our railway trains—to take the most striking instance—we have far exceeded the size and considerably exceeded the speed of any walking or running animal. But, think for one moment! How have we done this? Simply by modifying the conditions under which the movement is accomplished. All animals, as far as nature has selected them, have been selected to exercise their powers under the conditions at the surface of the earth as these conditions exist; whereas our locomotive engines are possible only after the conditions have been completely modified by the construction of railways. Even our carriages and teams of horses would be altogether useless were it not for the existence of good roads. Thus we see that it is not as a constructor of locomotive machines that man has won the race, but by laboriously modifying the conditions which these machines have to meet.

Thus, in considering the liability to accident in the means of locomotion constructed by man, as compares with the liability to accidents met by animals in the exercise of their natural powers, it must be remembered that failure in the due maintenance of the two conditions—the improved road and the rule of the road—may be important elements in the former.

As far as ships are concerned, the last is the only condition. Here there is no improvement in the road, and no artificial guides, such as in the railway insist, to a certain extent, on the maintenance of the rule of the road.

In virtue of the smoothness of the railway we can pass the natural limits as regards size and speed of locomotive structures, and in virtue of the rule of the road we do away to some extent with the necessity for such comparatively great powers of stopping and turning as those possessed by swift animals; but we cannot do away altogether with the necessity for such powers, and in spite of all possible improvement in the conditions under which locomotion takes place, it would appear that the minimum of these powers consistent with safety remains fixed by the surrounding conditions. For there are certain conditions which play an essential, although it may be thought a secondary, part in our means of locomotion, which conditions, it may appear, that we have no power to modify to any great extent. These relate to the distances at which we can see and hear. Although by the use of telescopes we may increase the optical power of our eyes to almost any extent, it is found that such an increase is of no use to us in guiding ourselves or our structures amongst obstacles on the earth's surface; the limits to the distance at which we can see such obstacles being fixed by the form of the earth's surface and the condition of the atmosphere, rather than by the power of our eyes. These conditions vary greatly. In some places, and at some times, a signal may be visible for miles, while at other times it may not be visible many yards. When the conditions of the atmosphere are such that they limit this distance, no increase in the power of our eyes would make any difference; and their power is amply sufficient when the distance is not otherwise limited.

The effect of these conditions is much more important as regards safe navigation at sea than as regards the driving of our trains. Dwelling for one moment on ships, we see at once how this limit to the distance at which we can depend on our eyes and ears to warn us of danger, must place a limit on the size and speed of our vessels. Large and swift vessels will only have the same room in which to manœuvre out of danger as small ones. Hence, in order that they may as successfully accomplish such manœuvres,

the large and swift vessels should have proportionately much greater powers of stopping, starting and turning than small vessels. Up to the present time, however, no means have been found of rendering the manœuvring of large ships proportionately greater than the manœuvring power of small ships.

To railway trains the same law does not apply with the same force; still, it does apply. We have not made our system of distance signalling so complete but that there do continually arise cases in which the first warning the engine-driver receives of an obstruction ahead is from the obstruction itself; and under these circumstances the chance of safety lies in the power of stopping the train within the limited distance. In such cases the power of stopping with a heavy fast train, in order to give the same chance of safety, must be proportionately greater than with a slower and lighter train.

It is certain that we have not as yet developed to the utmost the brake power on our trains, or the steering and stopping powers of our ships; but it is certain that there is a limit to these powers, and the only question is, how far are we from this limit? This brings me to what is, to me, the most pleasant part of my subject, namely, the consideration of certain progressive steps that have recently been made, which, although they have not attracted much notice, are nevertheless extremely important to our means of locomotion, and are also important as showing that however far happy guess-work may carry us towards perfection, perfection itself is rarely, if ever, to be attained except by scientific method.

Up to within the last few years our attention has been so closely occupied in developing and perfecting the primary power in our means of locomotion, that but little notice has been paid to such secondary considerations as the powers of stopping, starting, or turning, as the case may be; for these such appliances as came at once to hand were at first deemed sufficient; thus hand brakes on those parts of the train where they could be at once applied, and the rudder and hand wheel, such as may be said to have grown on the sterns of ships, were accepted without question. And it was only when we had so far perfected our locomotive structures as regards what may be called their locomotive functions that they have outrun our means of holding them; and when the alterations in the conditions consequent on the increase of traffic (of which I shall have more to say presently) have increased the necessity for greater powers of avoiding each other, we find ourselves driven to consider how far the power of stopping and turning may be improved.

As regards railway trains the question has been very widely taken up. The great prize held out to the inventor of the best continuous brake brought many able competitors into the field, while the urgency of the case has led to the adoption of much more direct means of testing the merits of the various inventions than ever fell to the good fortune of other inventors.

The result appears likely to be very instructive, apart from the direct object involved. It appears likely to afford an illustration of the fact that it is no use attempting the solution of such a problem except by the thorough and scientific method.

The stopping power arising from a single brake was known to depend on the tightness with which the brake blocks were screwed against the wheels up to a certain point; and it was apparently obvious that the tighter the better until the wheels no longer revolved—until, in fact, the wheels were skidded—to produce the greatest effect; therefore, it was thought that all the guard or driver had to do was to skid his wheels. Hence, when an emergency arose, the brakes were invariably screwed home and the wheels skidded. This practice, which has prevailed without question for forty years, is an instance of how far general experience can be depended on to remove a misconception. It is now found for the first time that by skidding the wheels the brake loses nearly half its greatest power of stopping the train. If the brake is applied with the greatest force short of skidding the wheels, the train will stop in something like half the distance required if the wheels are skidded.

How many lives have been sacrificed to this misconception it is not pleasant to think. Thanks to Captain Galton, it

is now removed, and it now only remains to choose the best means of applying the brakes so as to produce the greatest effect. Captain Galton has shown us the greatest stopping power we can obtain from one pair of wheels, and when we have succeeded in obtaining this from every pair of wheels on a train we shall have reached the minimum limit of our stopping power. But this is something like four times greater than the stopping power of ordinary trains.

Turning now to the manœuvring powers of steamships, I come to the subject which has engaged no small part of my attention for several years. The manœuvring powers of ships involve not only their power of stopping, but also their means of turning, and as regards improvement, the question of turning is the more important, for, as regards powers of stopping, a sailing ship has none other than that of turning her head into the wind; while with steam ships their greatest stopping power is developed by the reversal of their engines; and as they are all provided with the power to reverse, the only question is as to the rapidity with which it can be accomplished; and in this respect there is not great room for improvement. So far it has been the almost universal custom to reverse the engines by hand, and in the case of large engines the operation might occupy as much as thirty seconds, which would be time lost. Recently, however, steam reversing gear has come into vogue for large vessels, and by means of this the engines can be reversed by a mere turn of the wrist. We cannot, therefore, hope to increase the powers which vessels have of stopping themselves. As regards a vessel's power of turning, however, it is different. Taking screw-steamships as being the most important class of ships, and those to which, owing to their great speed, manœuvring powers are most important, we may see from the very great number of collisions in which screw-steamers take a part that, as at present sent to sea, the turning powers of these vessels are altogether insufficient. We all saw an authoritative statement that there had been upwards of seventy collisions in the Thames alone within twelve months, and that in by far the greater part of these collisions a screw-steamship was involved. The insufficiency of the turning powers of screw steamers has long been acknowledged by all those who have to do with them; but, strange to say, until within the last few years, no systematic attempts had been made to remedy the evil. It has been with the steering of screw steamers just as it was with the stopping of railway trains; the rudder and hand wheel, like the brakes on the engine and tender, came ready to hand when steamers were first introduced. And hitherto gross misconception has prevailed. It may be that the fact of the rudder and wheel having held its own for so long on sailing ships led to the conviction that it was already proved to afford the best means of steering, and as the rudder of the steamer was itself similar to that of the sailing vessel, and was similarly placed—namely, at the stern—it was assumed that it must produce the same effect. Such views would gather strength from the fact that in paddle steamships the rudder was found to answer its purpose as well as in the sailing ships. At any rate, for some twenty years no attempts were made to investigate the action of the rudder in screw-steamers, although from the time of the first screw-steamer going to sea anomalies in the steering presented themselves.

The action of a rudder at first sight appears to be so simple and obvious that it seems as if nobody thought of looking closer into the question. The rudder appears to act the simple part of a guide to the stern of the ship. When straight the rudder allows the ship to go straight on, but when it is turned it then guides the stern of the ship out of the direction in which the head is moving, and so causes the ship to turn. This is the apparent action of the rudder, and this would be its action if the ship did not offer any resistance to be turned. Owing to this resistance, however, and to the yielding nature of the water, the rudder does not act the part of a rigid guide to the stern of the ship, but only exerts what may be called a tendency to guide the stern. This, also, is to a certain extent obvious. And it is also obvious that by increasing the size of the rudder the tendency which it exerts to guide the stern will be increased. But what is not obvious, and what was not seen until

recent years is, that the tendency which the rudder exerts is not due solely to the forces which act between the water and the rudder, but to the increased pressure of the water which the rudder causes against that side of the ship towards which it is turned. The importance of this fact being entirely overlooked, it was not seen that the opening of a large space, such as the screw-way immediately in front of the rudder must in itself greatly diminish the tendency of the rudder to guide the ship. And further, such was the confidence in what may be called the obvious action of the rudder, that when it was found, as it was immediately on the introduction of screws, that, no matter how fast a vessel might be going through the water, if the screw was stopped or reversed the action of the rudder was not only feeble but uncertain, it was not supposed that this effect was due to any change in the tendency which the rudder exerted to turn the ship, but that it was due to the tendency which the screw exerted to counteract the effect of the rudder.

This blind confidence in the consistent action of the rudder, whatever may appear to the contrary, is so strong even at the present day, that, although from his own experience when manœuvring his ship in rivers and in port, every captain and pilot knows that his rudder is all but useless to him whenever his screw is stopped or reversed, and his vessel still be moving forward slowly, numerous pilots and captains adhere to the opinion that such would not be the case if the vessel were moving fast, for then, they argue, that the action of the rudder would be sufficient to counteract the action of the screw; and so great is their confidence in this view that they never try the experiment but wait until a collision is imminent, and then when, perhaps, as in the case of the *Konig Wilhelm* and the *Kurfurst*, the ship, with her screw reversed, pursues her own unguided way right into the sides of another, they refuse to give up their confidence in their rudder, and maintain, in spite of all evidence to the contrary, that their orders could not have been obeyed. The whole error arises from a failure to grasp the circumstances on which the action of the rudder depends. As long, and only as long as the water is rushing backwards past the rudder, will the rudder exert its normal tendency to guide the ship.

This is no mere theory. For, at the instance of a committee of the British Association, experiments to test these conclusions have been made on twelve steamers ranging from 4000 tons downwards; and in every case it is found that, no matter how fast the ship may be going, the instant the screw is reversed the action of the rudder is also reversed, and rendered comparatively feeble. It is therefore now conclusively shown that it was a misconception to suppose that the rudder would exert its usual influence with its screw stopped or reversed. And there can be no doubt that but for this misconception, many collisions might have been prevented.

The result of these experiments has been to bring to light what the manœuvring power of screw-steamers really is, and hence to clear the way to making the best possible use of that power.

Inefficient as a rudder on a screw-steamer must always be under certain circumstances, with large vessels its inefficiency is greatly increased by the insufficient means provided for turning it in case of emergency.

This evil might at once be remedied. Nothing is easier than to apply some power in place of the hand-wheel. Various contrivances for doing this have already been devised; and there is no doubt that the inventor of the best steering apparatus will secure a prize nearly, if not quite equal to that which will fall to the inventor of the best brake. The experience just mentioned as regards brakes may, however, be taken as a caution by those whose interest it is to find the best steering apparatus. Just as the question of the best brake is now found to lie beyond the mere means of applying it, so the best steering apparatus may be found to involve more than the mere means of turning the rudder.

It may be that the whole power of the engines of a ship will be brought to bear in bringing her round. Indeed, this has been already done in the instance of twin screws; and certain recent inventions are said to apply this power at still greater advantage. As regards the turning power of ships, therefore, it is

clear that although there doubtless is a limit, yet, owing primarily to ignorance as to what the turning powers of our screw-steamers really are, and also to the insufficient power now applied to turn the rudders, we are far from having reached the limit; and we may fairly hope that the risk at present attending the navigation of screw-steamers will, inasmuch as it depends on the want of turning power, be considerably reduced.

That we shall eventually develop to the utmost the powers of stopping and turning, whether on railways or on ships, and make use of all our scientific knowledge to discover those methods, may, I think, well be argued from the progress of late years. Although time has not allowed me to enter upon them in this address, there are many other circumstances under our control which affect the risk of locomotion beside the adequacy of the powers of manœuvring. And it is very satisfactory to notice that as regards one of these circumstances, and the one to which, until recently, accidents were mainly to be attributed, we appear, at all events, as judging from the accidents of this year, to have reached perfection. This is the adequacy of the strength of our structures. It is but rarely now that we hear of a railway axle, a rail, a beam, or even a boiler, breaking under its legitimate load. This certainly has only been reached by the most elaborate research, aided by scientific knowledge, and by the institution of most careful systems of tests and periodic inspection. But these have all been done, and we may fairly hope that what has been accomplished in one direction will be followed in others until we shall have substituted throughout every department of the manufacture and working of our structures a thoroughly understood art for what was a few years ago merely a field for ingenuity.

But it must not be imagined that all the future improvements there may be in the stopping power of our trains or in the turning power of our steamboats, or in whatever may affect their safety, will all be allowed to go to diminish the risk. As the risk with structures at their present sizes and moving at their present speeds is diminished, it will probably be as it has been—the sizes and speed will be increased, and more than this. I have already mentioned the increased risk consequent on the increased traffic of our railways and the increased crowding of our seas. This crowding goes to form one of the conditions under which locomotion has to be accomplished; and it is most important to notice that this crowding can itself only be limited by the increased risk which it causes.

Inasmuch as the risk of locomotion depends upon crowding so far, any diminution to risk which may be accomplished by increasing the manœuvring powers of our locomotive structures seems likely to be followed by increased traffic and crowding, and thus the advantage derived on the one hand may be balanced by the disadvantage on the other.

It thus appears that after all precautions risk is a necessity of locomotion, and that the speed and size of our structures as well as the extent of the possible traffic are limited by the risk. And it may well be asked, what, then, is the limit to the risk? This is a question of morality. The limit to the risk is the extent of risk to which we are willing to run. To accomplish some object or even to save ourselves trouble we are all of us willing to run some risk. Let our system of working be ever so perfect, the immunity from accidents will result in neglect, and this must culminate in accidents. The loss of the *Eurydice* appears to have been a marked instance of this, as does also the Sittingbourne accident, and it does not appear impossible that this may also have to be said of the loss of the *Princess Alice.*

Notwithstanding all this, statistics show us that the risks are and have been steadily diminishing. Nor is this diminution of risk other than we should expect. As novices we put up with that which experience teaches us to withstand, and hence, as we become more familiar with the incidents of traveling, we come to object to risks of travelers and responsibilities of officials which we know may be reduced.

It is proposed to hold an international industrial exhibition in Glasgow in 1880, the matter being in the hands of a number of influential citizens headed by the Lord Provost.

THE RECTANGLES THAT MAY BE INSCRIBED IN A GIVEN RECTANGLE.

By Professor W. ALLAN.

Written for Van Nostrand's Engineering Magazine.

Having seen several allusions to this problem of late I am induced to send you the following discussion of it. The problem has a useful application in the construction of Howe trusses and of similar structures.

I. To determine generally the rectangles that may be inscribed in a given rectangle, ABCD.

Assume some point as H, on the shorter side of the given rectangle, as one of the vertices of an inscribed rectangle. Let its distance from A be $= x$. Then through this point describe a circle with its center at O, the center of ABCD. The points in which this circle cuts the sides of ABCD are the points of the vertices of the inscribed rectangles that are possible when our first assumed point is one of these vertices. Each of the eight points gotten may serve as one of the vertices of two rectangles (like those having a common vertex at F). The two rectangles that may be drawn at each set of two points will evidently in every case be like those at F. No other rectangle, save those in the figure, can be inscribed with a vertex at F.

These rectangles have some pretty relations.

Let a=AB=shorter, and b=AC= longer side of given rectangle. Let AF $=y$, AH$=x$. Then FC$=b-y$ and HB $=a-x=$AP. From the similar triangles AFP and FCK, we have

$$\text{AP} : \text{FC} : : \text{AF} : \text{CK}=\text{AH} \therefore a-x : b-y : : y : x$$

whence

$$y^2-x^2-by+ax=o \qquad (1)$$

and the value of x in terms of y is

$$x=\frac{a}{2}\pm\sqrt{\frac{a^2}{4}+y^2-by}$$

Let s and p be the sides of the inscribed rectangles. Referring to the smaller of two inscribed in Fig. 1 we see that it, together with four triangles, make up the area of the given rectangle which is equal to ab. The triangles are the two equal ones AFH and GLD, and the other two equal ones FCL and GHB. The area of the first two $= xy$, and of the second

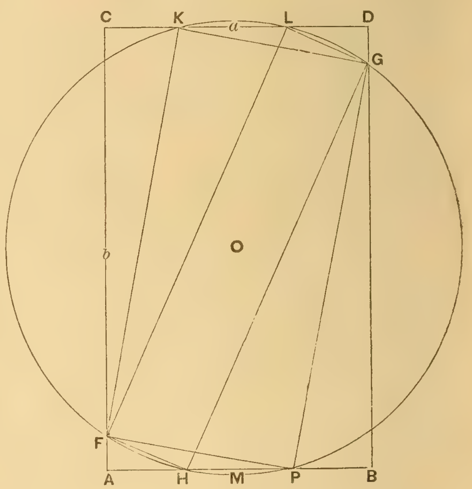


Fig. 1.

two $=(a-x)\ (b-y)$. The area of the rectangle FG$=sp$. Hence

$$(a-x)\ (b-y)+xy+sp=ab$$

$$(b-y)\left\{\frac{a}{2}\pm\sqrt{\frac{a^2}{4}+y^2-by}\right\}$$

$$+y\left\{\frac{a}{2}\pm\sqrt{\frac{a^2}{4}+y^2-by}\right\}+sp=ab$$

$$\therefore sp=\frac{ab}{2}\mp(b-y)\sqrt{\frac{a^2}{4}+y^2-by} \qquad (2)$$

The two values of the area sp correspond to the two rectangles with vertices at F. The *sum* of these two rectangles is seen to be always$=ab=$area of the given rectangle. As the point H is carried towards A, the smaller rectangle diminishes, and the other increases until at the limit one becomes the diagonal AD, and the other becomes the given rectangle itself. As H is assumed nearer and nearer to M (the middle point of AC) the two inscribed rectangles approach each other in size, and when H coincides with M, they become equal, and each is=one half the circumscribed rectangle, ABCD.

II. To determine the sides of the

blocks on which diagonals of a Howe truss abut, so that the faces may be perpendicular to the diagonals.

The face, or hypothenuse of the block (FH, Fig. 1) is equal to the breadth of the brace, and is the dimension given. The relation between this and one of the sides of the block leads, as Prof. Woods remarks in his book, to an equation of the fourth degree, which is insoluble.

But the relation between the *two sides* of the block is given by equation (1)

$$y^2-x^2-by+ax=o$$

This is the equation of an Equilateral Hyperbola, which is shown in Fig. 2.

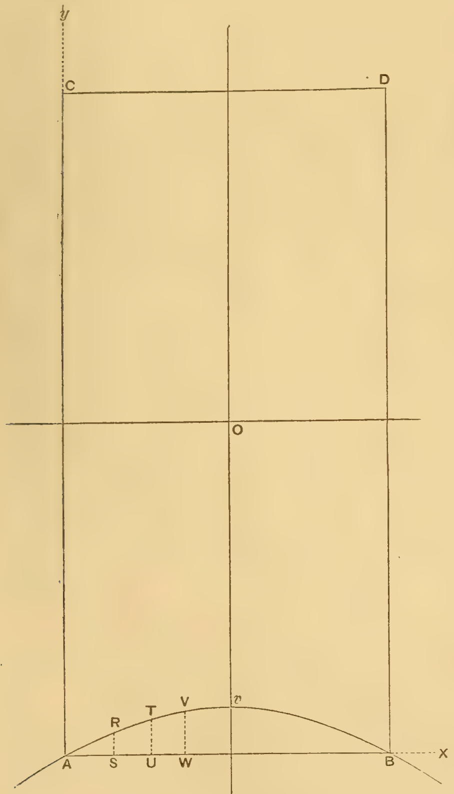


Fig. 2.

Transposing the origin to O the center of ABCD, eq. (1) becomes

$$y^2-x^2=-\tfrac{1}{4}\,(a^2-b^2) \qquad (3)$$

And O is the center of the Hyperbola. The vertex is V, and the curve passes this A and B. With A as center and radius equal to the given breadth of the base describe a circle. At the point where this circle intersects the Hyperbola within the rectangle, draw the co-ordinates of the Hyperbola referred to A as origin. They are the sides of the block whose face equals the radius of the intersecting circle.

The form of the Hyperbola changes only with the values of a and b. A table may be readily constructed giving the values of the sides of the blocks for given faces when the values of a and b are fixed. The values of these sides may be obtained by measuring the co-ordinates on a carefully prepared drawing, or by measuring one co-ordinate, and then calculating the others by means of eq. (1). A specimen of such a table is appended, when b is taken=20 and a=10:

Face.	x	y	Face.	x	y
0.20	0.18	0.089	2.20	2.03	0.845
0.40	0.37	0.180	2.40	2.22	0.904
0.60	0.55	0.264	2.60	2.41	0.961
0.80	0.73	0.345	2.80	2.60	1.014
1.00	0.91	0.423	3.00	2.80	1.065
1.20	1.10	0.503	3.20	3.00	1.112
1.40	1.28	0.575	3.40	3.20	1.155
1.60	1.46	0.645	3.60	3.40	1.194
1.80	1.64	0.711	3.80	3.60	1.228
2.00	1.83	0.778	4.00	3.80	1.258

In the contribution of Prof. Haupt, published in the November number of our Magazine, the statement was made that the new survey of the Delaware River then in progress was "under the supervision of Capt. S. C. McCorkle." It is desired to explain that Mr. McCorkle was the assistant in charge of the local triangulation. "The topography of that portion of the river shores then being surveyed was under the direction of Assistant R. M. Bache, and the hydrography of the river was executed by Assistant H. L. Marindin, under the special supervision of Assistant Henry Mitchell."

The entire work was organized and directed by Hon. C. P. Patterson, Superintendent of the U. S. Coast and Geodetic Surveys.

ON A NEW METHOD OF DETECTING OVERSTRAIN IN IRON AND OTHER METALS, AND ON ITS APPLICATION IN THE INVESTIGATION OF THE CAUSES OF ACCIDENTS TO BRIDGES AND OTHER CONSTRUCTIONS.

By ROBERT H. THURSTON, C. E.

A Paper read before the American Society of Civil Engineers.

It has been shown by the writer* and by other investigators that, when a metal is subjected to stress exceeding that required to strain it beyond its original apparent, or "primitive," elastic limit, this primitive elastic limit becomes elevated, and that strain-diagrams obtained autographically, or by carefully plotting the results of well conducted tests of such metal, are "the *loci* of the successive limits of elasticity of the metal at the successive positions of set."†

It has been shown by the writer also that at the successive positions of set, strain being intermitted, a new elastic limit is, on renewing the application of the distorting force, found to exist at a point which approximately measures the magnitude of the load at the moment of intermission.‡

It has been still further shown by the writer, and by Commander Beardslee, U.S.N., by direct experiment in the Mechanical Laboratory of the Stevens Institute of Technology, and at the Washington Navy Yard, that the normal elastic limit, as exhibited on strain diagrams of tests conducted without intermission of stress, is exalted or depressed when intermission of distortion occurs, according as the metal belongs to the iron or to the tin class.§ This elevation of the normal elastic limit by intermitting strain is, as has been shown, varible in amount with different materials of the iron class and the rate at which this exaltation progresses is also variable. With the same material and under the same conditions of manufacture and of subsequent treatment, the rate of exaltation is quite definite and may be expressed by a very simple formula. The writer has experimented with bridge material, and Commander Beardslee has examined metal specially adapted for use in chain cables, for which latter purpose an iron is required, as in bridge building, to be tough as well as strong and uniform in structure and composition. The experiments of the latter investigator have extended to a wider range than have those of the writer, and the effect of the intermission of strains considerably exceeding the primitive elastic limit has been determined by him for periods of from one minute to one year.* From a study of the results of such researches and from a comparison with the latter investigation, which was found to be confirmatory of the deduction, the writer has found that, with such iron as is here described, the process of exaltation of the normal elastic limit due to any given degree of strain usually nearly reaches a maximum in the course of a few days of rest after strain, its progress being rapid at first and the rate of increase quickly diminishing with time. For good bridge irons, the amount of the excess of the exalted limit, as shown by subsequent test, above the stress at which the load had been previously removed may be expressed approximately by the formula:

$$E^1 = 5 \text{ Log. } T + 1.50 \text{ per cent.};$$

in which the time, T, is given in hours of rest after removal of the tensile stress which produced the noted stretch.

Thus, in the figure, which is a facsimile of a part of a strain-diagram produced by such an iron, during a test in which the intermission of stress was of too brief duration to cause an observable exaltation of the normal elastic limit in a diagram drawn on so small a scale, the point E is the primitive elastic limit

* See Trans. Am. Soc. C. E., 1874, *et. seq.*, *Journal Franklin Institute*, 1873; *Van Nostrand's Eclectic Engineering Magazine*, 1873, etc., etc.

† On the strength, etc., of Materials of Construction, 1874, Sec, 20.

‡ On the Mechanical Treatment of Metals; *Metallurgical Review*, 1877; *Engineering and Mining Journal*, 1877.

§ Trans. Am. Soc. C. E., 1877.

* The result on this investigation is completed and will be presented to the President of the United States by the United States Board appointed to test iron, steel, etc.

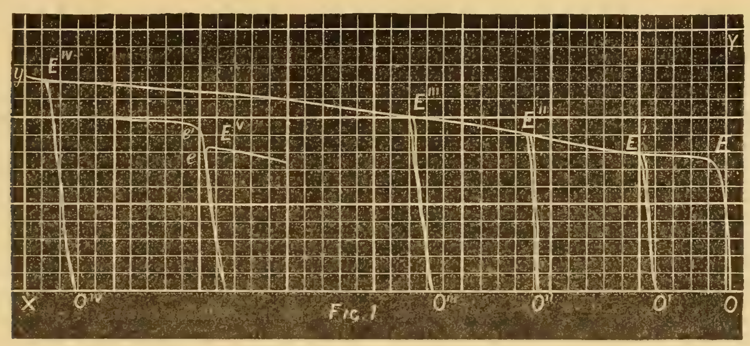


Fig. 1

of the material, and E^{I} E^{II} E^{III} E^{IV}, are the normal elastic limits corresponding to sets under loads which have strained it beyond that primitive elastic limit. In the example here illustrated, the primitive limit is found at about 20,000 pounds per square inch, or 1,400 kilograms per square centimeter, and the other points are those corresponding to loads of, respectively, 21,000, 22,500, 25,000 and 30,000 pounds on the inch, or to 1,470, 1,575, 1,750 and 2,100 kilograms on the square centimeter. The corresponding extensions, as shown on the diagram, are 1.25, 2.53, 4.50 and 6.78 per cent.

Had the stress been intermitted at either of these points any considerable period of time, there would have been observed a rise in the diagram as above stated like that shown in Fig. 1, at E^{V} the normal elastic limit e, being on subsequent test, found altered and a new limit, $é$, observed. The extent of this elevation of the limit would be the greater as the time of rest was greater, as already seen.

Thus, it is seen that a metal, once overstrained, carries, permanently, unmistakable evidence of the fact* and can be made to reveal the amount of such overstrain at any later time with a fair degree of accuracy. This evidence cannot be entirely destroyed, even by a moderate degree of annealing. Often, only annealing from a high heat, or reheating and reworking, can remove it absolutely Thus, too, a structure, broken down by causes producing overstrain in its tension members, or in its transversely loaded beams (and, probably, in compression members—although the writer is not yet fully assured of the latter), retains in every piece a register of the maximum load to which that piece has ever been subjected; and the strain-sheet of the structure, as strained at the instant of breaking down, can be thus laid down with a fair degree of certainty.

Here, then, when the work above detailed shall have been properly complemented with experimental determinations of the behavior of all the materials of general use in construction, may be found a means of tracing the overstrains which have resulted in the destruction or the injury of any iron or steel structure, and of ascertaining the cause and the method of its failure, in cases frequently happening in which they are indeterminable by any of the usual methods of investigation.

The fact of the normal variation of the elastic limit, as change of form progresses under gradually increased load, has been well established by the experiments of Hodgkinson, Clark, Mallett, and other English investigators; by Tresca, particularly, in France; by Werder and Bauschinger in Germany, and by Beardslee, the writer and others in the United States.

The exaltation of the series of normal limits so produced, still further, as shown by the writer and as seen in Fig. 1, by the intermission of strain, as at E^{V}, is also a matter of no uncertainty as to its character, although much more study is needed to determine the modifying effects of time of intermission on metals of the two great classes and of differing composition. The method above outlined

* The writer has found by subsequent tests, that transverse strain produces the same effect upon the elastic limit for tension.

of determining the extent of previous overstrain may therefore be expected to have many useful applications.

In illustration of an application of the facts thus reviewed to the determination of the causes and the method of the injury or the destruction of a structure, assume the existence of a set of conditions which is familiar to, probably, every engineer in the country who has seen much of the Howe truss, and of some other forms of bridges, as frequently built before the present generation of professional bridge builders effected a revolution in that department of engineering construction.

Suppose one of these bridges to have been built with a span of 150 feet and to have been given such proportions that, with a weight of 1,200 pounds per running foot and a load of one ton per running foot, the maximum stress on end-rods, or other members most strained, is as high as 20,000 pounds per square inch of section of metal. Suppose this bridge to have its tension members composed of a fair, but unrefined, iron, having an elastic limit at about 17,000 pounds per inch, and a tenacity of 45,000 to 48,000 pounds, and with an extensibility of about 20 per cent.

Suppose this structure to break down under a load exceeding that usually sustained in ordinary work, and the cause of the disaster to be "involved in mystery."

Suppose portions of the several tension members to be subsequently removed, and, a few days after the accident, to be carefully tested with the following results :

	Elastic Limit.	Tenacity.
Sample No. 1	16,500	46,000
" " 2	18,000	48,000
" " 3	30,000	48,000
" " 4	22,500	50,000
" " 5	25,000	52,000
" " 6	27,500	52,000
" " 7	28,000	52,000
" " 8	30,000	52,000
" " 9	32,000	53,000
" " 10	34,000	53,000

And that the extensibility is found to be as little as from ten to fifteen per cent.

Suppose it to be found that the tension members were straight bolts without upset ends, the threads being cut, as was once common, in such a manner that the section at the bottom of the thread is one-third less than the sectional area of the body of the bar. Suppose, finally, that the location of the tested pieces in the structure being noted, it is found that the stronger metal, having also the highest elastic limit, came from the neighborhood of the point at which the bridge gave way, and that the weakest metal and that exhibiting the lowest elastic limit came usually from points more or less remote from the break. It is not likely that in all cases the increase in the altitude of the elastic limit and the increase noted in the ultimate strength of the samples would exhibit a regular order coincident with the order of the rods as to position in the structure; since the magnitude and the arrangement of the bars would, to a certain extent, determine the relative amounts of strain thrown upon them by overloading any one part of the truss. For present purposes we may assume the order of arrangement to be thus coincident.

On examination of the figures as above given, the engineer would conclude : First, that the original apparent elastic limit of the iron used in this case must have been not far from 17,000 pounds per square inch, and that its tenacity was between 46,000 and 48,000 pounds; secondly, that this primitive elastic limit had been elevated, by subsequent loads exceeding that amount, to the higher figures given by the bars numbered from 3 to 10 inclusive; thirdly, that the ultimate strength of the material had been, in some examples given above, increased by similarly intermitted strain.

It would be concluded that the ordinary loads, such as had been carried previously to the entrance upon the bridge of that which caused its destruction, never exceeded, in their straining action, 16,500 pounds per square inch of section of tension rod at the part of the truss from which No. 1 had been taken, and that the other rods tested had carried, probably at the time of the accident, loads approximately equal to those required to strain them to the extent measured by their elastic limits at the time of testing them.

It would be concluded that the rod from which No. 10 was cut was either that most strained by the load, and therefore nearest the point of fracture of the

truss, or that it was very near that point, and it would be made the basis of comparison in further studying the case.

As this elastic limit approaches most nearly the breaking strength of the metal, we may apply the formula for the elevation of the elastic limit with time after intermitted strain which has been above given as derived from tests of a metal of very similar quality. Taking the time of intermission as one week, the extent of the increase has a probable value not far from $E' = 5 \log. 168 + 1.5 =$ nearly $12\frac{1}{2}$ per cent. The magnitude of the stress upon this piece at the time of the accident was therefore 34,000 less one-ninth of that value, or about 30,000 pounds per square inch of cross-section of the bar. This corresponds to about 45,000 pounds per square inch at the bottom of the thread, and is within five per cent. of the primitive breaking strength of the iron. The bar, if broken at the screwed portion, has therefore yielded either under a dead load which was at least equal to its maximum resistance, or under a smaller load acting so suddenly as to have the effect of a real "live load." Or the slight difference here noted may be due to a flaw at the point of fracture. However that may be, it is almost certain that the body of the rod has sustained a stress of not far from 30,000 pounds per square inch.

But it is found, on further investigation, that the load on the structure at the time of the accident was but sufficient to make the maximum stress on these rods—if properly distributed—20,000 pounds per square inch at the threaded part of the piece; which piece, it has been seen, has been broken by a strain nearly double that figure. The fact is at once inferable that the load came upon these members with such suddenness as to have at least the effect of a live load (as taken in the text-books) and giving a maximum stress equal to twice that produced by the same load gradually applied, *i.e.*, the case in which the load falls, through a height equal to the extension of the piece strained by it, the resistances being assumed to increase directly as the extension up to the point of rupture,—an assumption which is approximately correct for brittle materials like hard cast iron, but quite erroneous in the case of some ductile materials, which latter sometimes give a "work of ultimate resistance," amounting to three-fourths or even five-sixths of the product of maximum resistance by the extension.

This accident was therefore caused by the entrance upon the bridge of a load capable of straining the metal to about one-half of its ultimate strength, if slowly applied, but which, in consequence of its sudden application, doubled that stress.

This sudden action may have been a consequence either of its coming upon the structure at a very high speed, or a result of the loosening of a nut, or of the breaking of a part of either the bridge floor or of one of the trucks of the train. The latter occurrence, permiting the load to fall even a very small distance, would be sufficient.

This paper is not presented as a perfectly satisfactory statement of definite facts from which absolutely reliable conclusions can be drawn. The whole subject is deserving, however, of very careful and very extended experimental investigation, and the writer has been able to obtain but a small amount of satisfactory definite information in regard to it as yet. The figures given do not exactly represent those obtained from any actual case. They do, however, fairly illustrate the limited experience of the writer, and are nearly exact for at least one case; they may serve to indicate the possible value of the cautious application of the method here outlined of studying the causes of such accidents as are considered in the hypothetical case here taken.

The same method may sometimes be used to ascertain the probable cause of a boiler explosion by determining whether the metal has been subjected to overstrain in consequence of overpressure. The causes of accidents to machinery may also be thus detected, and many other applications will suggest themselves to every engineer.

Bituminous coal has been discovered near Aurora, in Nevada. It is but a few feet below the surface, and the seam is said to be about 7 ft. in thickness. If this turns out to be true, it will, in connection with the metalliferous discoveries in Nevada, be of the greatest importance.

A NEW GRAPHICAL CONSTRUCTION FOR DETERMINING THE MAXIMUM STRESSES IN THE WEB OF A BRIDGE TRUSS.

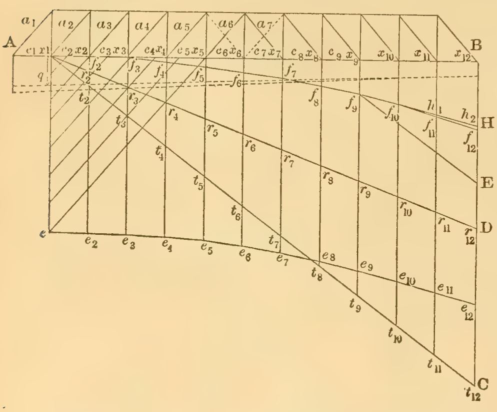
By WARD BALDWIN, University of Cincinnati.

Written for VAN NOSTRAND'S MAGAZINE.

IN Volume XVIII of this Magazine, page 26, Professor Eddy has given a graphical construction for finding the maximum stresses in a bridge truss. The determination of the maximum shearing stresses, in the article referred to, consists in successively subtracting the difference between the maximum shearing stresses on two consecutive joints from the total reaction of the pier when the live load covers the entire bridge. As thus constructed the errors are cumulative.

It is the object of this paper to propose a construction which will determine each of the maximum shearing stresses in a truss independently, and not as the sum or difference of several magnitudes. This, it is believed, permits of greater accuracy, than any construction heretofore proposed.

Suppose the bridge to be a through bridge. Let the live load consist of one or more locomotives which, to begin with, stand at n'' of the joints x_1 x_2, etc., at the left hand end of the truss, together with a uniform train of cars which covers the remaining joints.



Let s_1, s_2, etc., be the maximum shearing stresses at the joints x_1, x_2, etc.

w=the dead load on one joint.

w'=the load, due to the train of cars, on one joint.

$(w'+w'')$=the load, due to the engines, on one joint.

n=the number of the joint considered, reckoning from A.

n'=the number of panels in the truss.

n''=the number of joints loaded with locomotives.

$m=n'-n''$.

Now in the figure lay off $ex_1=r$, the reaction at the pier A when the live load covers the entire bridge in the manner above stated. The value of $Ex_1=r$ can be readily found by the principle of the lever. When the train moves off to the right, so that no live load rests on the joint x_1 and the locomotives stand on the n'' joints x_2, x_3, &c., then the reaction of the pier A has been diminished by the amount $\frac{n'-1}{n'}(w'+w'')$, and it has been increased by the amount $\frac{n'-(n''+1)}{n'}$, w''; as was proven in the article before referred to. Therefore the reaction of the pier A has been diminished by the difference of these quantities, that is to say, by the amount $\frac{1}{n'}[(n'-1)w'+n''w'']$. Now the maximum shear at the joint x_2 is this reaction diminished by the load at the joint x_1. Therefore the maximum shear at the joint x_2 is

$$s_2=r-w-\frac{1}{n'}[(n'-1)w'+n''w'']$$

By similar reasoning the maximum shearing stress at the joint x_3 is found to be

$$S_3=r-w-\frac{1}{n'}[(n'-1)w'+n''w'']$$
$$-w-\frac{1}{n'}[(n'-2)w'+n''w''].$$

Successive maximum shears may be computed in a similar manner, and in general the *shear* at the joint x_n is

$$s_n=r-w-\frac{1}{n'}[(n'-1)w'+n''w'']-w-$$

$$\frac{1}{n'}[(n'-2)w'+n''w'']-\ldots$$

$$-w-\frac{1}{n'}[(n'-(n-1)]w'+n''w''],$$

provided n is less than $n'-(n''-1)=m+1$, as will be shown presently; and s_n has a *maximum* value provided $n<\frac{n'}{2}+1$.

Now if for convenience we let $q=[w+\frac{1}{n'}\ (n'-1)w'+n''w'')\ ]$, then the values of the maximum shearing stresses may be expressed as follows:

$s_1=r$

$s_2=r-q.$

$s_3=r-q-q+\frac{w'}{n'}=r-\left(2q-\frac{w'}{n'}\right).$

$s_4=r-q-q+\frac{w'}{n'}-q+\frac{2w'}{n'}=r-\left(3q-\frac{3w'}{n'}\right)$

and in general it is evident that

$$s_n=r-\left\{(n-1)\ q-\frac{1+2+3+\ldots+(n-2)}{n'}w'\right\}=r-\left\{(n-1)q-\frac{(n-1)(n-2)}{2n'}w'\right\}(a)$$

Now in the figure lay off $BC=(n'-1)q$ and join cx_1 by the line t_1, t_2, etc. At x_3, x_4, etc., lay off $x_3\ f_3=\frac{w'}{n'}$, $x_4\ f_4=\frac{3w'}{n'}$ $x_6f_6=\frac{6w'}{n'}$, etc., and in general, $x_n\ f_n=\frac{(n-1)(n-2)}{2n'}w'$. Then the ordinates $f_2\ t_2$, $f_3\ t_3$, $f_4\ t_4$, etc., represent the amounts to be subtracted from r to obtain the maximum shearing stresses at the joints x_2, x_3, x_4, etc. For these ordinates are equal to q, $\left\{2q-\frac{w'}{n'}\right\}$, $\left\{3q-\frac{3w'}{n'}\right\}$, etc., respectively; and these amounts must be taken from r to obtain the maximum shearing stresses at the joints x_2, x_3, x_4, etc., as is shown by formula (a). Lay off these ordinates on $ex_1=r$, measuring from e. Then the distances from x_1 to the points thus found represent the maximum shearing stresses at the joints x_2, x_3, etc.

From e and the points thus found draw lines parallel to the inclined members of the web, viz., $a_1\ c_1$, $a_2\ c_2$, etc., terminating in the horizontal through x_1. Then these lines represent the maximum stress on the members $a_1\ c_1$, $a_2\ c_2$, etc.

From the points f_1, f_2, f_3, etc., lay off the vertical ordinates $f_1e=r$, $f_2e_2=r$, $f_3\ e_3=r$, etc. Then the ordinates $t_1\ e_1$, $t_2\ e_2$, $t_3\ e_3$, etc., represent the maximum shearing stresses at the joints x_1, x_2, x_3 etc. Then the point G shows where the sign of the shear changes, and therefore how far counters are needed.

On BC lay off $DC=(n'-1)w$ and join Dx_1 by the line r_1, r_2, etc. Then the ordinates $r_1\ e_1$, $r_2\ e_2$, $r_3\ e_3$, etc., represent the reactions of the pier A as the train moves towards the right and the live load is removed from one joint after another; for $r_1\ t_1=0$, $r_2\ t_2=w$, $r_3\ t_3=2w$, etc. . . . But 0, w, $2w$, $3w$, etc., are the amounts which must be taken from the reactions of the pier A to obtain the maximum shearing stresses at the joints x_1, x_2, x_3, etc.

Now when the train has moved so far to the right that the live load rests on only n'' joints, the live load consists of engines alone; and, reckoning from A, the number of the first joint loaded with the live load is $(n'-n'')=m$. To find the shearing stress at the next joint to the right, that is at the joint x_{m+1}, the live load is moved off of the joint x_m, and the reaction of the pier A is thus diminished by the amount $\frac{n''}{n'}(w'+w'')$. As the engine load on the joint next to B is at the same time moved to the pier B, the reaction of A is not affected by the additional load on B. Therefore the shearing stress at the joint x_{m+1} is less than the shearing stress at the joint x_m by an amount equal to $w+\frac{n''}{n'}\ (w'+w'')$. By similar reasoning we can also at once show that the shearing stress at the joint x_{m+2} is less than the shearing stress at the joint x_{m+1} by an amount equal to $w+\frac{n''-1}{n'}(w'+w'')$, etc.

Now, for convenience, let the ordinate f_mt_m equal p, and also let $w+\frac{n''}{n'}(w'+w'')$ equal h, then the shearing stresses at the joints x_{m+1}, x_{m+2}, are evidently,

$s_{m+1}=r-(p+h)$

$s_{m+2}=r-(p+[2h-\frac{1}{n'}(w'+w'')])$

$s_{m+3}=r-(p+[3h-\frac{3}{n'}(w'+w'')])$, etc

which shearing stresses have evidently a maximum value, provided the end of the live load has not yet passed the center of the bridge. This may be the case if the span is short, or if the value of n'' is great. Finally, at the joint n', the shearing stress is

$$s_{n'}=r-(p+[n''h-\frac{1+2+3+....+(n''-1)}{n'}(w'+w'')]$$
$$=r-(p[n''h-\frac{n''(n''-1)}{2n'}(w+w)]);$$

and this is the reaction of the pier B due to the dead load.

In the figure from the point f_m draw a line to E parallel to x_1c. From E lay off $EH=n''h$, and join f_m to H. From the points h_1, h_2, etc., lay off the ordinates

$$h_1\,fm{+}2=\frac{1}{n'}(w'+w''),\ h_2 fm{+}2=\frac{3}{n'}(w'+w''),\text{ etc.}$$

Then will the ordinates $fm{+}1$, $tm{+}1$, $fm{+}2$, $tm{+}2$, etc., represent the amounts to be taken from r to obtain the shearing stresses at the joints $xm{+}1$, $xm{+}2$, etc.; for these ordinates are equal to $p+h$, $p+2h-\frac{1}{n'}(w'+w'')$, etc. From the points f thus found lay off the distances $fm{+}1\ em{+}1=r$, $fm{+}2\ em{+}2+r$, etc.; then $tm{+}1\ em{+}1$, $tm{+}2\ em{+}2$, etc., represent the shearing stresses on the joints $xm{+}1$, $x\,m{+}2$, etc.

The ordinate $e_{n'}\ t_{n'}$ represents the shear at B when the live load has passed off of the bridge; therefore $e_{n'}\ t_{n'}$ is the reaction of B due to the dead load. The ordinate $e_{n'}r_{n'}$ represents the reaction of A when the live load has left the bridge, as is shown above, and is, therefore, the reaction at A due to the dead load. Hence, evidently, $e_{n'}$ should be equidistant from $t_{n'}$ and $r_{n'}$.

If, instead of an unsymmetrically distributed live load, a uniform live load covers the bridge and moves off to the right, the construction used to determine the shearing stresses after the live load consisted entirely of engines is applicable to the whole bridge, and p becomes zero.

If the bridge is a deck bridge instead of a through bridge, the ordinates $t_1\ e$, $t_2\ e_2$, $t_3\ e_3$, etc., represent the maximum stresses on the ties c_1a_2, c_2a_3, etc., instead of on the ties c_2a_2, c_3a_3, etc. But the maximum stresses on the inclined members are the same in a deck as in a through bridge, and therefore the number of counters is the same for both forms of bridge.

The construction proposed may be briefly stated as follows:

To determine the maximum shearing stresses, lay off $BC=(n'-1)\ [w+\frac{1}{n'}(n'-1)\ w'+n''w'')]=(n'-1)q$, and draw the line x_1C; at the joints x_2, x_3, etc., lay off distances equal to 0, $\frac{w'}{n'}$, $\frac{3w'}{n'}$ etc; then the ordinates between the points thus found and the line $x_1\ C$ are to be subtracted from $x_1e=r$, to obtain the maximum shearing stresses at the joints x_2, x_3, x_4, etc.

q may be found graphically by the construction given by Professor Eddy, as is shown in the figure, and the line $x_1\ t_2$ be prolonged to c. Then BC will equal $(n'-1)q$. The quantities 0, $\frac{w'}{n'}$, $\frac{3w'}{n'}$, $\frac{6w'}{n'}$, etc., are the terms of a regular series whose first differences are $\frac{1}{n'}.\ w'$, $\frac{2}{n'}.w'$, $\frac{3}{n'}.w'$, etc., in regular numerical order, and they may therefore be calculated mentally and laid off at once.

Suppose, for example, that in the figure the scale of lengths is 30 feet to an inch, and the scale of weights is 40 tons to an inch. Then

$ex_1=r=73.5$ tons,
$w=6$ tons,
$w'=6$ tons,
$w''=3$ tons,
$n'=12$, $n''=3$ and $m=9$.

Also $BC=(n'-1)q=11\times[6+\frac{1}{12}(66+9)]$
$=11\times12.25$ tons$=134.75$ tons,

$x_1\,f_1=0$, $x_2\ f_2=0$, $x_3\ f_3=0.5$ ton, $x_4\,f_4=1.5$ tons, $x_5\,f_5=3$ tons, $x_6\,f_6=5$ tons.

And the maximum shears are, by measurement,

$S_1=73.5$ tons, $S_2=61.25$ tons, $S_3=49.5$ tons, $S_4=38.25$ tons, $S_6=27.5$ tons.

The position of the point G shows that only one counter is needed on each side of the center. It is the practice to put in one or two more counters on each side of the center than is necessary for a static load.

ON THE EFFECT OF RIVER IMPROVEMENT WORKS.*

By JAMES DILLON, Mem. Inst. C.E.I.

From "Engineering."

The great floods, due to the unusual rainfall of late years, have caused so much damage and misery in different countries that the subject is at present engaging the serious attention of scientific men.

It is known that in the great majority of cases the discharging capacity of the rivers and their tributaries is insufficient to carry off the flood waters without overflowing their banks, due in a measure to the existence of numerous hard gravel and rock shoals, mill-dams, badly constructed bridges, and insufficient sectional areas, &c. To remove these defects it has hitherto been the practice to deal with a system of rivers, or at least with the main and principal tributaries belonging to one catchment basin (by catchment basin is meant the entire district of country unwatered by a river and its tributaries, it may, therefore, embrace mountains or lakes), and to endeavor to borrow money from Government or other parties to carry out the works necessary for the removal of the obstructions above referred to, commencing upon the lower reaches of the river system and carrying the works upwards. Many useful works have been carried out in different countries, particularly in Ireland, where the progress of the arterial drainage works, under 5 and 6 Vict., c. 39, up to July 31, 1863, was as follows: The total amount of loans obtained and expended under the direction of Government, previous to 1863, on river or arterial drainage works, equaled £2,390,612 (exclusive of the coast of Shannon), and the repayments in respect thereof, including interest, amounted on March 31, 1878, to £1,341,522. This money was expended on various river works extending over not less than 2000 miles of rivers and tributaries, the works being designed so as to convey the flood waters from 120 different catchment basins of an aggregate area of 6,358,358 statute acres. The object of these works was to relieve 266,736 statute acres of good land, at an average cost of £7 per acre, adjoining the 2000 miles of river banks and shores of lakes, from the injurious effects of flood waters. Particular attention should be paid to the fact that the ground covered with water was only $4\frac{1}{5}$ per cent., or about $\frac{1}{24}$ of the entire catchment basins, as this will have to be dwelt upon hereafter. The above works were executed by Drainage Commissioners appointed under 5 and 6 Vict., c. 89, and no doubt conferred great benefits on the country, but both the country and the Government concurred in thinking the outlay was too great, and further action as regards new works was suspended, under the 5 and 6 Vict. Then, in 1863, owing to previous agitation in and out of Parliament, the Government sanctioned a general drainage act being passed for Ireland authorizing private parties to form drainage districts (see Act 26 and 27 Vict. c. 88, and Acts passed amending the same), provided that two-thirds of the injured land in value are owned by parties assenting to the project, and if the two-thirds petition, the Government will grant the necessary money to to carry out the works, if satisfied with the financial prospects of the undertaking.

Progress of arterial drainage works in Ireland, under 26 and 27 Vict., c. 88, from 1863, to July 31, 1878, was as follows: Under this act the works for 37 districts have been sanctioned and are now nearly completed. Their effect has been to drain and free from floods not less than 71,000 statute acres, at a cost of £389,000, equal to an average outlay of not less than £5 9s. per acre as compared with £7 per acre under the 5th and 6th Vict. Notwithstanding that the above results as regards Ireland are so far satisfactory, still it is a fact that year by year such works are becoming more difficult of accomplishment, owing to the impossibility of adjusting the conflicting interests of the upland and lowland proprietors. If the lowland proprietors promote a scheme for the improvement of their larger and consequently more costly

* Read before Section G of the British Association: Dublin meeting.

sections of their rivers, they generally try to tax the upland proprietors for works that can confer no benefit upon them, while if the upland proprietors try to improve their smaller and less costly rivers they are opposed by the lowland proprietors, who contend that their floods are made worse by the drainage of the uplands, &c. The extent to which these supposed conflicting interests interfere with the carrying out of such works may be judged from the fact that the Board of Public Works in Ireland, in their report for 1877-78, announce that from Ireland last year there was only one application for a new drainage district, so that unless subsequent legislation proves more successful, there will be few if any useful works of this class carried out when those already sanctioned are completed.

It has occurred to the author, who has been entrusted with the expenditure of some £157,000 on rivers, or nearly one-half of the money expended on such works since 1863, under 26 and 27 Vict., that the principal objection to the extension of such works can be proved to be unfounded, viz., that the extension of arterial drainage or river works up country increases the volume of river floods sent down from the drained districts, to the injury of the low-land proprietors.

The following are the particulars of some arterial drainage works lately carried out under the direction of the author, which had not the effect of increasing the flood discharge. They are known as the Upper Inny Drainage Works, and were commenced in 1870. These works extend over 82 miles of rivers and tributaries, the catchment basin or area of country discharging its waters into this system of rivers extends over an area of 273 square miles, and its centre is situated about 53 miles to the west of Dublin, at a level of 211 feet above the sea, the rock formation being limestone.

The whole of the river works were designed so as to carry off the flood waters about 4 feet below the surface of land, which formerly saturated and covered with water 12,260 statute acres of land, equal to 7 per cent. of the catchment basin. During the progress of the works it was necessary to carry out extensive rock, gravel, and other excavations, and to rebuild some 60 bridges, the total cost of which will amount to some £60,000. The works under the author's charge were commenced near Lough Iron, at the point where the Lower Inny Works, carried out under the care of the Drainage Commissioners of Ireland, were suspended on account of their excessive cost and want of funds, &c., to proceed further up country. Previous to the commencement of the Upper Inny Drainage Works, the average summer discharge in the river from the upper district amounted to .0689 per acre per minute, and the average flood discharge to .4896 per acre per minute. After the execution of the works the average summer discharge at the same place amounted to .0827 per acre per minute, and the flood discharge to .4827 per acre per minute. Similar results have been obtained by the author in other districts, and it may be added that the Earl of Ross and Mr. Forsyth, late engineer to the Commissioners of Public Works of Ireland, both concur in his views on the subject.

It has been shown that in the above district, while the total area of the catchment basin amounted to 273 square miles or 175,000 acres, the ground covered with water along the 82 miles of rivers and tributaries amounted to only 12,250 acres, or about 7 per cent. of the whole catchment basin, and, further, that the average breadth of the flooded land equaled 75 statute perches, or 1237 feet. This is not an exceptional case, for it is already stated in this paper that in the other districts already executed, 120 in number, the total amount of flood water along the river flats covered only $4\frac{1}{5}$ per cent. of the catchment basin. From this it follows that there is not less than 93 per cent. of the Upper Inny district situated above flood level, so that 93 per cent. of the floods due to the rainfall falling upon the entire district could flow just as freely on to the 7 per cent. flooded lands along the river banks before the execution of the works as they could after the execution of said works.

It must not be forgotten that the flooded 7 per cent. is always more or less saturated with water, particularly in winter, and that when so saturated it can hold no additional water except the flood water flowing over its surface.

It is believed by many that this flood

water remains stationary, but this cannot be, inasmuch as the river valley has always (unless in very exceptional cases) a very perceptible fall, otherwise sufficient velocity would not have been given to the waters of the country to have cut any kind of river through its valley. From this it follows that whether the river banks are or are not flooded, the whole of the flood waters in the river valley are in motion until they rise to what is known as the maximum flood level. At this level the waters will only remain so long, as the maximum yield from the maximum rainfall in the district can keep them up to it. So that as long as the flood level remains stationary no further ponding of the flood waters can take place, and therefore the maximum flood due to the maximum rainfall will flow along the river valley for days and weeks without increasing in height, spreading over the country where the banks are low, and confining itself to the river where there are cliffs or high banks, but not exceeding the maximum flood level even at these points. If then the flood waters do not increase in height the whole flood discharge must be passing out of the district, and if this can occur before a river is enlarged or improved, enlarging a river channel can neither increase the rainfall nor the flood yield from same sent down to lowland proprietors.

Having shown that the sheets of flood waters spreading over a river valley are in constant motion, it will be observed that just as they commenced to rise because they could not get away before the flood waters came pouring into the river valley from the more distant portions of the catchment basin, so after the maximum floods have ceased to flow from the last named places into the main river valley these sheets of flood water fall in level, and in doing so increase the flood discharges towards the close of the wet season by the volume of water covering the river valley which would not have been there had the district been drained. It will be said if the effect of the arterial drainage works is to prevent the accumulation of large sheets of flood waters in a river valley, then the floods must be increased by the passing away of these waters.

The author believes this to be a mistake. He has already shown that the flooded ground seldom averages 7 per cent. of the catchment basins, and in the Inny district above referred to it equaled an average breadth of 1537 feet or 7 per cent. If then a number of tributary rivers with catchment basins some 2 miles in breadth, and some 8 or 10 miles in length, branch off at nearly right angles to the main river, along which this 7 per cent. flooded land exists; then if you divide these lateral catchment basins into 100 parts, allowing the 7 parts near the river to be flooded, it will be evident that the maximum flood due to the maximum rainfall on the seven parts, or 7 per cent. at the junction of the tributaries with the main river, will have passed away into the main river before the maximum floods from the second, third, or tenth miles, &c., could reach the last named junctions, were the rivers not dammed up with shoals, &c., so that the time required to allow of the river valleys being covered with water before the execution of the works would, if properly utilized, be more than sufficient to allow of said water passing down a properly constructed river channel before the maximum floods could reach the main river from the second, third, or tenth mile back from the main river. If this holds good in narrow tributary catchment basins, so will it be applicable to all forms of catchment basins, no matter what their direction with regard to the main channel. The author believes, then, that the effect of arterial drainage works is to enable the floods from the fractional 4, 7 or 8 per cent. flooded lands near the main arteries to pass off after execution of works many hours or days sooner, according to the magnitude and length of the rainfall and district than before execution of works; and that by securing a longer interval of time for the discharge of a flood of given magnitude, arterial drainage works cannot increase the maximum flood discharges of a district.

As this view of the case is confirmed by the author's observations, he invites discussion in order to test its accuracy. When once it is established that the floods in a river valley are not increased by the enlargement or improvement of either an upper or lower section of the river passing through said valley, the author

believes that the public and the Government would find it more practical to deal with the improvement of rivers in the following way:

Whenever any considerable portion of a country is flooded by the overflow of a river or its tributaries, and the parties injuriously affected are desirous of applying to Government through the Commissioners of Public Works in England, Ireland, or elsewhere, for a loan to improve their land, they should be required to furnish a section of the rivers to be improved, taking care to extend the sections down the river until a sufficient outfall is obtained for the successful carrying out of the proposed works. Should the Board of Works report in favor of the project, the treasury could advance the necessary funds, thus enabling useful works to be carried out under the superintendance of drainage boards acquainted with the localities with which their interests are connected, instead of losing many years in endeavoring to embrace all the districts or tributary districts in one large, costly and unmanageable scheme. By this method the works could be commenced in divisions corresponding to the natural sub-outfalls of the country, commencing at the fall nearest to or furthest from the sea.

Should this method be sanctioned by Government on any large scale, now that it is proposed to grant loans for river works, on a moiety of the proprietors assenting to the project instead of requiring two-thirds, as formerly, a great impetus would be given to the extension of such works, conferring great benefits upon the country by increasing the value of land, and giving at the same time additional employment, and circulating large sums of money among the working classes in the agricultural districts. Although the facts thus briefly set forth in this paper are now publicly brought forward by the author for the first time, still, in the case of the great Barrow river scheme which embraces a country of 625 square miles, he has succeeded in overcoming hostile opposition (based upon increased flooding) to its being executed in divisions instead of in one vast unmanageable whole. Of this work two divisions have already been sanctioned by Parliament, and are now nearly completed.

The object of the author in bringing forward these facts is that the practicability of dealing with large river systems in divisions, instead of in one whole, may become more universally known and acted upon.

ON THE MANUFACTURE OF ARTIFICIAL FUEL.

BY E. F. LOISEAU.

A Paper read before the American Institute of Mining Engineers.

UNTIL June, 1868, it had not been attempted, either in this country or abroad, to manufacture, by mechanical means, from anthracite coal-dust, artificial fuel for domestic use. Several attempts had been made to utilize coal-waste by converting it into a fuel for manufacturing purposes, but none of the processes were original, and they were merely applications of the well-known European processes and machinery, slightly modified by American ingenuity and mechanical skill. With one exception all those attempts have been failures.

The great difficulty in the application of European processes and machinery has always been the limited production and the excessive cost of the manufactured product, as compared with the cost of mining and preparing the ordinary anthracite coal for the market.

The only serious and intelligent attempt to manufacture, on a large scale, artificial fuel for manufacturing purposes has been made by the Anthracite Fuel Company, whose works are erected at Fort Ewen, near Rondout, New York. This company, organized under the auspices of the Delaware and Hudson Canal Company, had to go through the usual course of difficulties, breakages and disappointments, which seem to be the lot of every new industry. Thanks, however, to the energy and perseverence of

Mr. L. L. Crounsse, a gentleman of means, from Washington, D. C., the enterprise succeeded, and it is to-day established on a permanent basis.

In order to increase the production, and to reduce its cost, the Anthracite Fuel Company was compelled to change most of its plant, and to erect more powerful machinery, producing lumps of a larger size, almost twice the size of the lumps made previously by the same company. This increase in the size of the lumps has been resorted to in Europe as well as in this country, in order to increase the production; but the lumps, being large, require a strong draft for their combustion, and consequently the use of artificial fuel has been confined almost exclusively to steamers and locomotives.

In order to manufacture a fuel which could be used in all kinds of furnaces, it was evident that the lumps should not exceed a certain size, and machines for this purpose were invented by Mr. Revollier-Bietrix, of St. Etienne, France, and by Messrs. Mazeline and Couillard, of Havre; but the production of these machines, in 24 hours, did not exceed 48 gross tons, in lumps weighing, each, one kilogram, 250 grams. No better results have been obtained in Europe to this day, and no smaller lumps have been manufactured there.

The compressing machines, above referred to, are constructed on the principle of Gard's brick machines in this country. Circular horizontal tables, containing either stationary or movable molds, revolve under a pug mill, in the center of which is a vertical shaft, with knives placed at an angle. These knives force the materials into the molds. The bottom of the molds is formed by followers, fitting exactly, which travel on an inclined plane under the molding table, gradually compressing the materials, and finally expelling the brick-shaped lumps, which are afterwards removed by hand, or pushed by a scraper on a conveying belt.

The problem, therefore, was to obtain a large production in lumps of a small size, and my efforts for the last ten years have been directed toward the solution of that problem.

I devised and designed, to the best of my ability, several machines which my experience had told me were best adapted to the continuous and automatic production of lumps of a small size, the main machine being the press. I had previously made a good many experiments, on a small scale, which had demonstrated beyond a doubt the practicability of the process. A good many of our members will remember to have witnessed in Mauch Chunk, in 1874, the manufacture of the fuel by a small machine, which was the embryo of the large one erected at Port Richmond. As is usually the case, the large machine did not work as well as the small one; it had to be modified several times, according to what practical experience demonstrated to be an absolute necessity. One modification suggested another, until at last, in spite of all the prophecies to the contrary, I succeeded in getting the press to work in a very satisfactory way. The production is $137\frac{1}{2}$ tons in 10 hours, the lumps weighing but two ounces each.

I will give here a brief description of the moulding press:

Two rollers, each 30 inches in diameter, and 36 inches in length, contain on their surface semi-oval cavities, connected together by small channels, which allow the escape of air and excess of material, each cavity or recess communicating by four of those channels with the surrounding ones. These cavities extend in close proximity to each other, in regular rows over the whole length of the rollers, the recesses of every other row being intermediately between those of the adjoining row, in the nature of the cells of a honeycomb, so that small metallic contact surfaces are formed, and the entire surface of the roller is utilized for compressing the composition into lumps of an egg-shaped form. The shafts of the rollers are cast solid with the rollers, and they are $10\frac{1}{2}$ inches in diameter. Each roller weighs over a ton. On top of these is a hopper, 36 inches long and 30 inches wide, in which the materials to be compressed are discharged from the mixer. In this hopper a series of knives, screwed to a small horizontal shaft, revolve rapidly, and keep the materials in a granulated state.

When the materials to be compressed happened to contain too much water, which was often the case, the mixture was very plastic, and the lumps were spongy and unfit for use. When the

mixture contained the required amount of water, the rollers would spring, and would deliver nothing but half-lumps. Every means was resorted to in order to prevent the springing of the rollers, and to mold complete lumps. All sorts of contrivances, suggested by able mechanical engineers, were tried, without success. Considerable time was required, and a large amount of money was expended to obtain the desired result. The task had been given up by a good many as a hopeless one, still I persevered. I had observed that, when the hopper was almost empty, the shaking of the rollers stopped, and the half-lumps of the last rows remained in the molds, instead of being discharged on the conveyor below. I concluded from this fact, that the springing of the rollers was produced by an excess of material above the compressing point, and that if I could regulate the quantity of material a little above that point, the springing of the rollers would cease, and perfect lumps would be produced. The thought was a happy one. I devised several attachments to regulate the delivery of the materials on both rollers, with only partial success, until at last I concluded to muffle one roller entirely with sheet iron, and to deliver the materials on the other one. In the centre, above the point of contact of the two rollers, I placed an iron gate, 36 inches long, 3 inches thick, and 3 inches wide, guided at both ends inside of the hopper, and working up and down along those guides, by means of two long bolts, threaded at one end, passed through a stationary nut, fastened in a wooden cross-piece above the hopper and worked by small hand-wheels. By reducing or increasing the space between the bottom of the gate and the roller, more or less material was carried away by that roller. At the point of contact between the rollers, the materials which have been delivered on one roller are pushed into the cavities of the other one, and perfect lumps are formed and discharged on the conveyor below. The difficulty is entirely overcome, and the press has worked well ever since.

The coal dust accumulated in the yard is on swampy ground; the tide-water comes up to the middle of the lot, and the capillary attraction draws the water the coal-pile up as high as seven feet. During dry weather we obtained from the top of the pile coal sufficiently dry, but when it rained the coal dust was so wet that it clogged in the screen, in the chutes under the chain elevators, in the coal pocket and in the distributor. This was remedied by erecting a gravel-drying apparatus, composed of two drums, 18 feet in length and 36 inches in diameter, placed on an incline and heated underneath. The drums revolve slowly; the coal dust, as it comes from the yard, is fed at one end of each drum; it travels the entire length of the drums in five minutes, while being kept stirred by stationary lifters, fastened inside of the drums, and it is finally screened and discharged at the other end perfectly dried.

In the drying oven we had the next trouble. The first plan consisted in carrying the molded lumps through the oven in 40 minutes, on five endless wire-cloth belts, placed underneath each other, and geared together, so as to travel in opposite directions. The lumps falling from the rollers on the upper belt were conveyed into the oven at the speed of 12 feet in one minute, traveling the whole length of the oven and falling from one belt to another, until they emerged from the oven on the lower belt, to be discharged therefrom into the waterproofing machine.

When the five wire-cloth belts were loaded, the oven contained about six tons of coal. Under the weight of the fuel the belts would stretch, sag, and drop the greatest part of the lumps on the bottom of the oven, where they broke to pieces. The belts were changed several times, and replaced by others of smaller mesh and stronger wire; additional rollers were placed under the wire-cloth to stop the sagging as much as possible, but the belts would stretch in spite of all, and the use of wire-cloth as conveyors had to be abandoned.

It was also ascertained that the fuel was imperfectly dried, and that the contraction of the clay, used as a cement, could not take place when the lumps remained only 40 minutes in the oven. The solidity of the lumps was found to depend entirely upon the length of time during which they remained in the oven, and the following tests demonstrated this fact to a certainty:

Three lumps which had been in the

oven during 40 minutes supported a weight of 99 pounds before being crushed.

Three lumps which remained in the oven one hour and ten minutes stood a weight of 148 pounds before being crushed.

Three lumps which had remained in the oven during six hours stood a weight of 371 pounds before giving way.

Each one of these lumps came from the same mixer, and contained the same materials, and in the same proportions.

The problem then was not only to modify the oven so that it would hold sufficient fuel during six hours, but to modify it in such a way that the fuel could be discharged by its own gravity, when sufficiently baked. To do this seemed an insuperable difficulty. I studied for weeks one plan after another, until at last I conceived one which I thought would answer the purpose. I submitted the plan to competent authority, and it was approved as a feasible and practicable one.

The plan consisted in doing entirely away with wire-cloth, in suppressing the four lower conveyors, and in using for the top conveyor sections of sheet iron bolted to bridge links of malleable iron, placed at regular intervals, in three endless link chains running in grooves and moved by toothed wheels. The fuel was to be removed from this top conveyor by gates thrown slantingly across it, and it would slide down iron chutes, forming a spiral, upon bars of wrought iron set at an angle across the oven, and resting upon cast-iron racks, placed at the lowest point, 18 inches above the flue. Through those bars and through the mass of the fuel, the hot air was to pass and dry the fuel.

When the fuel was baked it was to be discharged by its own gravity, and through a series of gates, on an outside conveyor, placed alongside the oven, and made of sections of sheet iron, bolted to link chains like the top conveyor. This outside conveyor was to dump the fuel into an elevator, and from this elevator the lumps were to be delivered into the waterproofing machine.

The alterations described above were made, and the whole oven became in this way a kind of coal-bin, holding very near one hundred tons of fuel.

When the oven, modified as stated, was tried for the first time, it contained nearly one hundred tons of good lumps. It was heated to about 300° Fahrenheit, and in about four hours the whole mass of fuel was on fire. It required ten men working two days and one night to extinguish the fire. The fuel was entirely spoiled, but no injury was done to the walls of the oven, or to the inside fixtures of the same. In order to avoid such an accident in the future, the cast-iron flues were covered with loose bricks. Three times in succession the oven was again filled, heated, and when it was supposed that the lumps were sufficiently baked, the discharge gates were opened, and the fuel was found to be as moist as when it entered the oven.

The oven was allowed to cool, and was carefully examined by Dr. Charles M. Cresson, of this city, and it was ascertained by him that the openings for the admission of air, and for the escape of the evaporated moisture were much too small. The fuel, as it seems, had simply been submitted to a steam bath, instead of being baked, and the defect could be easily remedied, according to Dr. Cresson's opinion, by a false sheet-iron bottom, which would bring the air in close contact with the iron flues, and at the same time prevent the fuel from catching fire by radiation from the flues. Dr. Cresson advised larger openings for the admission of air and for the outlet of moisture. The sizes of those openings have been carefully calculated, and there is no doubt that when these alterations shall have been made, the working of the oven will be as satisfactory as that of the balance of the machinery.

The waterproofing process has been tried several times, and has been found to work well. Instead of condensing the vapors of the benzine, as was at first intended, we were compelled, in order to avoid accidents, to remove them by a suction fan. These vapors pass through a system of pipes; they are here mixed with twenty times their volume of atmospheric air, so as to render them innocuous, and they are then expelled above the roof of the building.

It must not be forgotten that the process applied, and the machines used, were entirely novel, and considering all the difficulties in the way of success, the

results obtained have been very satisfactory.

The large amount of money expended, the many disappointments which have occurred, and, above all, the depressed condition of the coal trade during the last two years, have discouraged some of our stockholders, and we have thus been placed in a financial condition which has prevented the completion of the experiment. In a few days, however, the financial difficulties will also be entirely overcome, a new company will be reorganized, and I hope that in a few weeks the works will be in successful operation, and the fuel will be in the market.

ON THE DISCHARGE OF SEWAGE INTO TIDAL RIVERS.*

By H. LAW.

From "Engineering."

THE present paper is intended as a contribution towards the important subject of the treatment and conservation of rivers.

Mr. William Hope, whose name has long been before the public in connection with this subject, in a recent letter addressed to *Engineering*, makes the startling assertion that the pollution of the river Thames by the sewage is cumulative; that is to say, in other words, that there is no fixed limit to the percentage of sewage pollution, which must go on in an ever-increasing ratio.

It is, therefore, of great importance to examine this matter with some care, in order to determine with exactness what are the actual condition of tidal rivers into which certain quantities of polluting matter are discharged.

Now, a tidal river may be looked upon as a reservoir of a very elongated form, subject to the following conditions, namely:

1. That it is supplied with water of three different qualities, from three different sources, that is to say:

The water constantly draining off of the surface of the basin forming the watershed of the river, and that derived from the land springs which find vent in its bed; this we will designate river water.

The water entering the mouth of the river from the sea, under tidal influence, which we will disgtinguish as sea water.

The polluted water discharged from the sewers, which we will term sewage.

2. That the actual and relative quantities of these are not constant, but vary within certain limits.

3. That the supply of sea water is not constant, but intermittent, being poured into the reservoir for a certain number of hours, and then, for a certain period, the reservoir being allowed to discharge a proportion of its contents.

Now in the actual state of things the river water may, and usually does, enter the channel of the river by tributary streams at various points, and the sewage may be discharged at many different places, while the quantity of both the river water and the sewage will vary according to the amount of the rainfall and other circumstances; but in inquiring as to the ultimate degree of pollution of the river, we may simplify the question under consideration, without in any way invalidating the result, by assuming that the whole of the river water enters by the upper extremity of the channel, or elongated reservoir, and that its flow is uniform and equal to the mean quantity taken over a lengthened period; further, that the sewage is all collected and discharged into the channel or reservoir at some intermediate point, and that its flow is also uniform, and equal to the mean quantity; furthermore, that the sea water is poured in at the lower extremity of the channel at regular intervals for a certain period, and that the only discharge of the contents of the channel or reservoir is at its lower extremity, also for a definite time, and in such a manner that for a certain period in every twelve hours the contents of the reservoir would be accumulating, and, as a consequence, the level of its surface rising, and that

* Read before Section G of the British Association: Dublin meeting.

then for a certain time, the contents would be diminishing and the level of its surface falling.

Now, the subject of our inquiry is, what, under the conditions assumed above, will be the mean or average composition of the water contained in the reservoir or river?

In order to obtain a practical result, let us investigate this question, adopting the mean values for the several quantities which apply in the case of the river Thames.

First, then, as to the extent and capacity of the reservoir. The tidal portion of the River Thames extends from Yantlet Creek, where the jurisdiction of the Conservators commences, to Teddington Lock, a total distance of 318,160 feet, or about 60¼ miles; its breadth varies from about 200 feet to 22,800 feet, or about 4⅓ miles at its mouth. Its superficial area at high water is 58,182,380 square feet above London Bridge, and 1,054,362,660 square feet below the same, making a total of 1,112,545,040 square feet, or about 40 square miles. At low water the superficial area above London Bridge is 38,807,800 square feet, and that below the same 681,786,610 square feet, making a total of 720,594,410 square feet, or nearly 26 square miles.

The mean range of the tide at the mouth, that is, at Yantlet Creek, is 14 feet; at London Bridge 17 feet 4 inches, and at Teddington Lock 3 feet.

The mean tidal capacity of the river, that is to say, the difference in the quantity of the water which is contained by the river at high water and at low water, with the above stated mean range of tide, is 616,634,400 cubic feet above London Bridge, and 13,562,903,900 cubic feet below the same, making a total of 14,179,538,300 cubic feet.

Now, as has been already stated, this body of water is derived from three sources, viz., the sea, the land drainage, the sewage: and it is necessary in the next place to ascertain the relative quantities furnished from each of these sources.

The downward flow of the Thames at Seething Wells, near Kingston, a short distance above Teddington Weir, and beyond the influence of the tides, was gauged daily for eleven years by Mr. Taylor, and the result obtained was an average annual discharge of 500,000 millions of gallons, which, reduced to a mean daily flow, would equal 1,369,800,000 gallons. This is, however, the drainage of only 3676 square miles, whereas the whole area of the Thames Valley is 5162 square miles; and if we assume, as may very fairly be done, that the quantity discharged from the lower portion is in the same proportion, we shall have for the total mean daily discharge from the drainage of the Thames Valley 1,923,626,000 gallons, a quantity which, we may incidentally remark, is about one-third of the rainfall.

From the above, however, must be deducted 100,000,000 gallons, which is daily abstracted from the river above Teddington Weir, for the supply of water to the metropolis, leaving a total quantity of 1,823,626,000 gallons, or 291,780,160 cubic feet for the mean daily discharge, being 145,890,080 cubic feet as the mean quantity of river water contributed each tide.

The mean quantity of the sewage discharged into the Thames from the two outfalls at Barking and Crossness may be taken at 120,000,000 gallons daily, equivalent to 9,600,000 cubic feet every tide, making with the river water a total of 155,490,080 cubic feet, which being deducted from the mean quantity already stated as that which enters the river every tide, we have 14,024,048,220 cubic feet as the mean quantity of sea water which enters the Thames every tide.

It is difficult to form a true idea of the relative values of such large numbers, and, therefore, it is better to reduce them to a percentage, when we obtain the following result namely, that the mean composition of the Thames water is as follows, namely:

Sea water	98.91
River water	1.02
Sewage water	.07
	100.00

That is to say, the actual mean quantity of sewage in the tidal portion of the River Thames, extending from Teddington to Yantlet Creek is only 0.07 per cent., or otherwise expressed, only one 1477th part of its whole bulk.

Futhermore, it must be borne in mind that owing to the circumstance of the river water always being delivered at the upper end of the elongated reservoir, no

less than sixty miles in length, while the ultimate discharge is wholly from the lower extremity, the composition of the water varies greatly, being always much freer from sea water and sewage in the upper portion than the lower. In point of fact, it must be evident that in the case of a stream which has a certain quantity of river water, that is, as we have already defined it, water derived from the rainfall and discharged into the river by surface drainage and land springs, there must always be a point, even in the tidal portion, above which no contamination can exist from sea water or other matters which enter the river near the lower portion of its course.

The foregoing is a statement of the average result, the actual amount of contamination by sewage at any given time and place must depend upon the recent past rainfall and upon the state and condition of the tides, but at no time and under no circumstances can the amount of the sewage contained in the Thames water be raised sufficiently above its average value of one 1477th part to produre any appreciable pollution, far less to afford any ground for the statments to which previous allusion has been made.

Generally, it is obvious that considerable care should be taken in the selection of the points of discharge of sewage matter into tidal rivers, and of the times and conditions of such discharge.

One of the most essential of these conditions being that the sewage shall be so discharged as to be carried into the main stream, in such a manner that it may be commingled with a sufficient bulk of water; and that water traveling with sufficient velocity to insure no deposition by precipitation of any of the contained matter being possible.

Again, the point selected should be one where the course of the stream is direct, and not subject to eddies, or sets upon either of the shores; so as to insure the thorough absorption and mixture of the sewage with the main bulk of the river, and to prevent any deposit taking place upon the foreshores.

Where populous places exist upon the banks of the river, it is, of course, necessary that no sensible pollution of the stream from sewage matter should be suffered in the neighborhood of such place, and in most cases there are two modes of obtaining this result, namely, by the removal of the point of discharge to a sufficient distance below the town, and by the discharge of the sewage during only a limited portion of the ebb tide. To effect the first object, it will be necessary to construct sewers probably of a considerable length, and to effect the second, to form tanks of sufficient capacity to permit the sewage to accumulate during the intervals between the times of discharge.

It is obvious, therefore, that there is an ample field for the skill of the engineer to be exercised, in so designing works for the discharge of sewage into tidal rivers, as to fulfil in a perfect manner the foregoing essential conditions, and that it is under such conditions only that such discharge should be permitted.

THE INFLUENCE OF SILICON ON CAST STEEL

By M. POURCEL, of Terre Noire.

From "Iron."

The following note was communicated to the Societé de l'Industrie Minérale, at the September meeting. "The writer begged to recall the attention of members to the subject of cast steels, homogeneous and free from blow-holes, which was discussed at considerable length at one of the Paris meetings, when different opinions were advanced as to the advantages and disadvantages of obtaining these steels, more particularly with reference to quality, either by mechanical or chemical means. In the first place, if the gas is prevented from escaping from the steel, and consequently the blow-hole from forming, we shut up the wolf in the sheep-fold—so M. Grüner affirms (*ou enferme le loup dans la*

bergerie)—which is certainly a disadvantage.

But does this disadvantage really exist? The wolf is the oxygen, or rather the carbonic acid, and when a bath of steel has been previously deoxidised by the addition of sufficient manganese, and the perfect malleability of the metal when hot, has been assured before casting, by means of test samples, it may be taken for granted that it no longer contains oxide of iron, except the merest trace. But nevertheless, at the moment of solidification, the steel gives off carbonic oxide gas; and whether this gas exists in solution, or whether it arises from the intermolecular reaction of the carbide of iron of the steel on the oxide of iron, which is formed during the action of casting, it is not less the cause of the silvery blow-holes so frequently met with in blocks of steel."

The theory of these reactions put forward by the writer, at the November meeting, 1876, was based on most carefully observed facts, and no new fact has come to light up to the present time to contradict it. Whatever mechanical means may be employed to prevent the formation of the blow hole in the mass of steel at the moment of its solidification, if the metal has been deoxidised before casting, and contains an excess of .2 per cent. to .5 per cent. of manganese, it is certain that the quality will in no way be altered, and that the result will be most satisfactory. In the second place, another opinion advanced by Mr. Vicaire, gives the preference to mechanical action over every chemical reaction, as the former introduces no foreign element into the steel. Mr. Vicaire is of opinion, for instance, that the silicide of manganese added as the chemical reagent to prevent the formation of blow-holes, affects the qualities of the metal, by leaving in it a foreign element, namely, silicon, although in very small proportions, say .2 per cent. to .3 per cent. In this case, let us examine to what extent the metal is affected—if at all. The writer sets aside the possibility of obtaining practically a metal free from silicon, a question of considerable interest, and upon which he touched in speaking of the "influence of the nature of the pots used in the manufacture of cast (crucible) steel, of the chemical composition of the steel," at the July meeting, 1877. It may be mentioned:

(1) That the best brands of English tool steel, made in crucibles from cemented Swedish iron, rarely contain less than .1 per cent. silicon, and generally from .1 per cent. to .3 per cent. (1) That Krupp's cast steel, according to the analyses of M. Boussingault, contains a remarkable quantity of silicon, .3 per cent. to 5 per cent.; and (3) that French cast steels in no wise vary in this respect from similar English steels; and lastly, that the metal which for so long was considered the ideal of steel, was never free from silicon.

We have, therefore, only to examine whether two steels, differing only in their chemical composition by one or two thousandths of silicon, really show any wide difference in their physical and mechanical qualities. All the experiments that have been made in various quarters to determine the action of silicon in steel, have led to the same conclusion, namely, "that it plays the part of carbon, although less energetically," Swedish chemists agree on this point, and Mr. Akerman, whose opinion is highly valued in Sweden, considers that, in order to obtain steel of the mildest description, the silicon as well as the carbon should be eliminated. The writer also holds this view. Only traces of silicon are allowed to remain in plate steel manufactured at Terre Noire. An examination of "Experiments on the Qualities of Plates," published by the "Jernkotoret" of Stockholm, will show that Terre Noire Siemens-Martin steel plate contains: Carbon, 0.20 per cent.; silicon, 0.025 per cent.; phosphorus, 0-08 per cent.; manganese, 0.235 per cent.; and sulphur, 0.02.

The action of silicon may be classed with that of the hardening constituents of steel—carbon and manganese; but compared to that of carbon its influence is slight. Professor Mrazek, whose work on this subject has been published in the *Bulletin de l'Industrie Minérale* concludes from his experiments that, as far as manipulation in the hot state is concerned, the effect of silicon is three or four times less than that of carbon; and, similarly, Mr. Mussy states in a communication to the *Bulletin*, that ingots had been manufactured at his works contain-

ing as much as 2 per cent. silicon, but little carbon and manganese, and had undergone, without difficulty, the necessary hammering and rolling for plates and similar articles. The writer must, however, express surprise at Mr. Mussy's statement that the steel in question contained but little manganese: he can hardly understand how a cast metal containing 1 per cent. of silicon only, even with very little carbon, can stand the work of the hammer, unless it contains .6 to .8 per cent. of manganese.

Assuredly a metal containing 2 per cent. of carbon would act very differently. Consequently, under ordinary circumstances, when the percentage of carbon permits of easy manipulation when hot, *i.e.*, when this percentage of carbon remains between .7 per cent. to .9 per cent., or even 1 per cent., the presence of an additional .1 per cent. or .2 per cent. of silicon cannot affect to any extent the malleability of the metal in the hot state.

But is there any necessity for examining the behavior in the hot state of a metal destined for the production of castings which have to undergo no hammering, but simply finishing in the lathe or planing machine? It appears rather that the question should be confined to determining whether the presence of silicon within the specified limits of .2 per cent. or .3 per cent. influences the mechanical properties of the metal, its resistance to shock, tensile strain, crushing strain, etc. Professor Mrazek, who has made experiments to determine the tenacity of the metal cold, admits that $\frac{4}{10}$ths per cent. of silicon do not diminish the tenacity more than $\frac{1}{10}$th per cent. of carbon. Amongst the thousands of tests for tensile strains and resistence to shock made at Terre Noire, on cast steels containing at least .1 per cent. of silicon, and at most .4 per cent., one fact has been established, namely, that two steels containing equal quantities or nearly so of carbon, manganese, and phosphorus, both being equally pure, and differing only by .1 per cent. to .3 per cent. of silicon, give mechanical results differing but slightly. That containing most silicon shows rather less elongation but higher tensile strain, and behaves as if it were slightly more carburized. Without attempting to fix an exact law, it has been observed that the increase of tensile strain given by .1 per cent. of carbon amounts to 6 kilos per square millimetre on the average; whilst the increase due to .1 per cent. silicon scarcely exceeds 1 kilo, and that the difference in resistance to shock is scarcely appreciable with variations of .1 per cent. to .3 per cent. of silicon.

It remains to be examined whether the properties of annealing and tempering are influenced by the presence of silicon. The researches of Colonel Caron, on the behavior of silicon in steels, has proved the property of this body to displace, at a red heat, the carbon from its combination with iron.

Colonel Caron has come to the conclusion that in steels containing silicon—he does not say how much—the carbon, after several heatings, passes into the graphitic form, and that the metal, consequently, loses the property of tempering.

Silicon, as shown by Mrazek, affects the tempering property but very slightly, its influence in this respect, as compared with carbon and manganese, is hardly appreciable. This is a very favorable property, and entirely precludes the fear of the metal being rendered fragile on tempering by the incorporation of a few thousandths of silicon. As regards the effect of silicon in diminishing the tempering properties of the steel after repeated heatings, its influence might, no doubt, be injurious in tool steel.

A tool will lose its hardness more or less rapidly in its work, and one of the chief qualities of tool steel is the faculty which permits of its being tempered and softened almost indefinitely. But this objection almost vanishes when we come to consider the steel required for castings of large dimensions, which require no hammering. It is a matter of slight importance that this metal should have a tendency to lose its tempering power after a certain number of heatings; besides, the proof of this tendency is still wanting.

In fact, it must be borne in mind that the conclusions arrived at by Colonel Caron were deduced from a limited number of tests made on a particular metal, where carbon and silicon were incorporated alone in the presence of each other, in the absence of manganese.

Now, in steel castings of large size, manganese is always present, and its presence modifies the tendency of silicon to diminish the amount of carbon combined with the iron. The writer adduces, as an instance, a pig-iron containing 3 per cent. silicon, 2 per cent. carbon, and .1 per cent. to .2 per cent. manganese, which showed a grey fracture with the carbon in the graphitic state, and a sudden cooling, failed to effect the solution of the carbon. Cast into an iron mold, it took no chill. As soon, however, as the amount of manganese is increased, the effect of the silicon is partly neutralized, and when the proportion of these two bodies is that of the equivalents $\frac{Mn}{Si}$, the grey specks in the fracture disappear and it becomes perfectly white. As a rule, pig-iron containing silicon and manganese in the specified proportions, takes chill "in proportion to the percentage of carbon," as an ordinary pig-iron free from these bodies. If the same observation be applied to the case of steel, it will be readily understood why a metal containing at the same time silicon and manganese, in definite proportion, may show results differing from those obtained by Colonel Caron, and may acquire by tempering all the qualities of superior metal.

As regards the proportion of manganese to be left in the steel, it will vary from .2 per cent. to .5 per cent. for .01 per cent. to .35 per cent. of silicon. This law is equally applicable to phosphorus. A good idea of the changes of grain of solid cast steels, under the influence of tempering, may be obtained from the fractures exhibited in the Terre Noire Pavilion at the Exhibition; the detailed catalogue of each sample gives all the figures of the results obtained from mechanical tests before and after tempering, as well as the chemical composition.

We may, therefore, reasonably conclude that the presence of silicon to the extent of .1 per cent. to .3 per cent. in solid cast steel obtained by chemical reaction, affects neither its physical nor mechanical qualities. Recourse must be had to infinitely small quantities (*faire valoir des infiniments petits*) to determine the difference existing between this steel and steel obtained without the addition of silicide of manganese by any mechanical process whatever.

A DISCUSSION OF THE CONTINUOUS GIRDER WITH EXAMPLES.

By M. S. HUDGINS.

Written for Van Nostrand's Magazine.

In the year 1825 Navier first announced the now well-known principle, that the extension and compression of the fibers of a beam on both sides of the neutral axis, or more correctly, the neutral plane were proportional to their distances from the neutral plane. From this he deduced the equation of the elastic line, and applied it to the continuous girder of special form.

In 1857 Clapeyron made known his celebrated theorem of the three moments; that is, the consideration of the moments over the piers, and the formation of an equation between the moments over any three consecutive piers. He applied it only to uniform loads over a whole girder or span. The theory of continuous girders is considered to be due mainly to Clapeyron. This publication attracted the attention of the mathematicians to the subject, and it has since been greatly improved, but Clapeyron may be considered as having made the foundation for them all.

In 1862 Winkler gave a general theory, and in the same year a like work was given by Bresse. Winkler, in 1867, put forth a general theory with suitable analytical formulæ thus extending his former work. Weyrauch, in 1873 published the fullest and most complete work on the subject, leaving little to be added or desired. The French and Ger-

man mathematicians have done most of the work in this department of applied mathematics, very little having been done by any others.

Before going into our subject we will introduce without demonstration the simple formulae for curvature, slope and deflection, as they will come in farther on in the discussion. Their proof can be found in the ordinary books on applied mechanics. Let r be the radius of curvature of the beam, M the moment of resistance at any cross-section, and I the moment of inertia. Then we will have $\frac{1}{r}=\frac{M}{EI}$, E being the modulus of elasticity. The maximum value of r can be found for any particular load by the substitution for M of its value for such load, and then applying the maximum and minimum test. Let i be the slope of the beam at any point, and i_0 its slope at the origin, then $i=i_0+\int_0^{x'}\frac{dx}{r}$. If there is no slope at the origin $i=\int_0^{x'}\frac{dx}{r}$.(1). The steepest slope under a given load W is $i_1=\frac{M'''Wc^2}{En'bh^3}$ found from (1) by integration and proper substitution. M''' is a factor depending upon the distribution of the load, manner of support, and form of cross-section, $c=l$ or $2l$ as the beam is supported at one or both ends, $n'=\frac{I}{bh^3}$ (1'), b the breadth and h the depth of the circumscribing rectangle. The mode of calculation of m''' will be given in the examples.

The deflection $v=\int_0^{x'} idx$ (2) under a given load W, $v=\frac{n'''Wc^3}{En'bh^3}$ (2') as found from equation (2). n''' depends upon the distribution of the load, mode of support and form of section. It will be calculated in the examples. There is much similarity between these formulae for slope and deflection.

In discontinuous beams the calculation of the shearing force, bending moment, curvature, slope and deflection are direct processes, going step by step from the calculation of one of these quantities to that of another. In continuous beams the process is one of elimination between these quantities. A beam is in the state of a continuous beam when a pair of equal and opposite couples act on it in the vertical, longitudinal, sectional planes at its points of support, of such magnitude as to maintain its longitudinal axis horizontal there. In the figure let CC represent a beam supported at C and C and so fixed as to have its longitudinal axis horizontal at those points instead of having the slope i which it would have were it not fixed or continuous.

At each of the points C and C there is a uniformly-varying horizontal stress, a thrust below and pull above the neutral plane; the moment of this couple is equal and opposite to the moment of the couple maintaining the beam horizontal at C; knowing that moment we can find the stress on the material; then the effect on the curvature, slope, deflection and strength of the beam.

To do this we proceed as follows:—Determine the slope i_1 which the beam would have at C were it not held horizontal there under the constant moment M_1, $i_1'=\int_0^{x'}\frac{1}{r}dx=\int_0^{c}\frac{M_1}{EI}dx=\frac{M_1C_1}{EI}$ and $M_1=\frac{EIi_1}{C}$. This value of M_1 is the moment of the stresses in the beam at the point C. Since it tends to produce convexity upward we call it $-M_1$. The load on the beam will tend to produce convexity downwards. Let M be the moment of flexure at any point of the beam were it simply supported at C and C. The actual moment at any point will now be $M-M_1$. The substitution of this value for M in the formulæ for curvature, slope and deflection will show the change in these quantities produced by making the beam horizontal over the points of support or making it continuous. Where M is greater than M_1 the beam will be convex downwards, where less, convex upwards; where $M=M_1$ the moment of flexure, and consequently the curvature vanishes; these are called points of contrary flexure; at these points thebeam is subject to shearing force only.

(Ex. 1). Let us apply these principles to a beam of uniform section symmetri-

cally loaded. Our formula for the slope gives $i_1=\frac{m'''Wc^2}{En'bh^3},=\frac{2m''mWc^2}{En'bh^3}$, m''' being $=2m''m$, where $m=M_0\div Wl(3)M_0$ being the maximum bending moment in a free beam. We have found $M_1=\frac{EIi_1}{c}=\frac{n'Ebh^3i_1}{c}$ since $I=n'bh^3$ see eq. (1′), substituting for i_1 its value, $M_1=2m''mWc=m''mWl=m''M_0$ from eq. (3).

We have now to determine m''. The value of i the slope may be written

$$(4)\ i=\int\frac{MI_0}{IM_0}\cdot\frac{M_0}{EI_0}dx=\frac{M_0}{EI_0}\int\frac{MI_0}{IM_0}dx$$
$$=\frac{mWl}{En'bh^3}\int_0^c\frac{MI_0}{IM_0}dx=\frac{mWl}{En'bh^3}m''c,$$

I_0 being the max. moment of inertia, $\frac{MI_0}{IM_0}$ is a numerical ratio, and m'' is the sum of the various values of this ratio, or $m''c=\int_0^c\frac{MI_0}{IM_0}dx$. In this case $M=\frac{c-x}{2}W$. $M_0=\frac{cW}{2}$, and the beam being of uniform cross-section $\frac{I_0}{I}=1$, and $\frac{M}{M_0}=1-\frac{x}{c}$ $\therefore m''c=\int_0^c\left\{1-\frac{x}{c}\right\}dx=\frac{1}{2}c$ $\therefore m''=\frac{1}{2}$, $m=M_0\div Wl=\frac{lW}{4}\div lW=\frac{1}{4}$, $m'''=2mm''=\frac{1}{4}$. Let M_0' be the actual bending moment at D. Then $M_0'=M_0-M_1=M_0-m''M_0=(1-m'')M_0$. The greatest moment of flexure must be either at D or C, or at both if they are equal, but for a uniform section, m'' is never less than $\frac{1}{2}$ $\therefore$ the greatest moment may be at C or at C and D together, but never at D alone.

The deflection is found by subtracting that due to the uniform moment M_1 from that which the beam would have were it simply supported at C and C. We proceed thus: The deflection as found in eq. (2′) is

$$v=\frac{n'''Wc^3}{En'bh^3}=\frac{2mn''Wc^2\frac{l}{2}}{En'bh^3},$$

n''' being taken equal $2mn''$ where m has been explained, and n'' will be found farther on. $mWl=M_0$ and $n'bh^3=I$ $\therefore v=\frac{n''M_0c^2}{EI}$, but $M_0=\frac{M_1}{m''}$ $\therefore$ $v=\frac{n''}{m''}\frac{M_1c^2}{EI}$ = the deflection the beam would have were it simply supported at C and C. This must be diminished by the deflections due to the uniform moment M_1. The curvature due to that moment is $\frac{1}{r}=\frac{M_1}{EI}$, $\therefore$ the slope is $i=\int_0^x\frac{dx}{r}=\int_0^x\frac{M_1}{EI}dx=\frac{M_1x}{EI}$, and the deflection $v'=\int_0^c i\,dx=\int_0^c\frac{M_1x}{EI}dx=\frac{M_1c^2}{2EI}$.

Now the true deflection of the beam equals $v-v'=v_1=\left\{\frac{n''}{m''}-\frac{1}{2}\right\}\frac{M_1c^2}{EI}$ equals, (since $M_1=m''M_0$), $\left\{n''-\frac{m''}{2}\right\}\frac{M_0c^2}{EI}$.

From this we see that by fixing the ends or making the beam continuous it is made stiffer in the ratio n'' to $\left\{n''-\frac{m''}{2}\right\}$, n'' is obtained as follows, $v=\int i\,dx$ which from equation (4) can be written $v=\int\int\frac{MI_0}{IM_0}\frac{M_0}{EI_0}dx^2=\frac{mWl}{En'bh^3}\int\int\frac{MI_0}{M_0I}dx^2=\frac{mWl}{En'bh^3}n''c^2$ $\therefore n''c^2=\int\int\frac{MI_0}{M_0I}dx^2$. Now in this case, as has been shown, $\frac{MI_0}{M_0I}=1-\frac{x}{c}$, $\therefore$ $n''c^2=\int_0^c\int_0^x\left\{1-\frac{x}{c}\right\}dx^2=\frac{1}{3}c^2$ $\therefore$ $n''=\frac{1}{3}$ and as $n'''=2mn''$, but m has been shown equal to $\frac{1}{4}$ in this case $\therefore n'''=2.\frac{1}{4}.\frac{1}{3}=\frac{1}{6}$.

The actual moment of flexure is $M-M_1=M-m''M_0=M-\frac{1}{2}M_0=M\frac{c-x}{2}-\frac{1}{4}Wc=\frac{W(c-2x)}{4}$ $\frac{1}{r}=\frac{M}{EI}=\frac{W(c-2x)}{4EI}$ $r=\frac{4EI}{W}\cdot\frac{1}{c-2x}$. The point at which r is a maximum can be found thus; $\frac{dr}{dx}=\frac{8EI}{W}\cdot\frac{1}{(c-2x)}2$, putting it equal to o we get $x=\frac{1}{2}c$. The point at which r is a maximum and, consequently, the curvature a minimum. The points of contrary flexure are found by solving the equation $M-M_1=o$ or $W\frac{c-x}{2}-\frac{1}{4}Wc=o$ whence $x=\frac{1}{2}c$, therefore as we should have ex-

pected the points of flexure are points of minimum curvature. The slope $i=\int_o^{x'} \frac{dx}{r}=\int_o^{x'} \frac{W(c-2x)}{4EI}dx=\frac{W}{4EI}(cx'-x'^2)$.

We will now determine the equation of the elastic line and apply it to this particular case. We have for the radius of curvature $\frac{1}{r}=\frac{M}{EI}$, or $EI\frac{1}{r}=M$ (5) but from the formula for the radius of curvature we have $r=\frac{\left\{1+\left(\frac{dy}{dx}\right)^2\right\}^{\frac{3}{2}}}{\frac{d^2y}{dx^2}}$, but the curvature being very small $\left\{\frac{dy}{dx}\right\}^2$ may be neglected in comparison with unity $\therefore r=\frac{1}{\frac{d^2y}{dx^2}}$ or $\frac{1}{r}=\frac{d^2y}{dx^2}$ substituting this value of $\frac{1}{r}$ in equation (5) we get $EI\frac{d^2y}{dx^2}=M$. The equation of the elastic line in cartesian cöordinates. The value of M for this case as has been shown is $\frac{Wc}{4}-\frac{Wx}{2}$. Substituting this in the eq. of the elastic line we have $EI\frac{d^2y}{dx^2}=\frac{Wc}{4}-\frac{Wx}{2}$ or $\frac{d^2y}{dx^2}=\frac{1}{EI}\left\{\frac{Wc}{4}-\frac{Wx}{2}\right\}$ integrating $\frac{dy}{dx}=\frac{1}{EI}\left\{\frac{Wc}{4}x-\frac{Wx^2}{4}\right\}+C_0$ making $x=o$ $C_1=\frac{dy}{dx}$ the tangent of the angle made by the tangent at the origin $\therefore \frac{dy}{dx}=\frac{1}{EI}\left\{\frac{Wc}{4x}-\frac{Wx^2}{4}\right\}+t_1$ integrating again $y=\frac{1}{EI}\left\{\frac{Wc}{8}+^2-\frac{W}{12}+^3\right\}+t_1xt$ a construction which disappears by making $y=o$ when $x=o$.

If now the beam is horizontal at the origin, or perfectly continuous, $t_1=o$ and the eq. of the elastic line is $Y=\frac{1}{EI}\left\{\frac{cx^2}{8}-\frac{x^3}{12}\right\}W$. Let us now find the points of inflection of this curve and see if they agree with the points already found. Placing $\frac{d^2y}{dx^2}=o$ we find $\frac{c}{4}-\frac{x}{2}=o$ or $x=\frac{c}{2}$ $\frac{d^2y}{dx^2}=\infty$ gives $x=\infty$ and does not apply. Now substituting in $\frac{d^2y}{dx^2}$ respectively $\left\{\frac{c}{2}+h\right\}$ and $\left\{\frac{c}{2}-h\right\}$ we find it changes sign $\therefore$ at $x=\frac{c}{2}$ there is a point of inflection as has been shown by the solution of the eq. $M-M_1=o$. Solving the eq. $\frac{dy}{dx}=o$ $x=c$ $\therefore$ the point of max. deflection is at the center as would be expected. After having found the points of inflection A and A, the beam can be treated as though it were composed of three simple beams. First, as a beam CA fastened at C and loaded at A. Second, as a beam ADA supported at both ends A and A. Third, as a beam AC fastened at C and loaded at A. And the slope, curve and deflection may be found by the solution of these cases of simple beams. In the same way if the beam extended on over other piers it could be revolved into simple beams, and discussed as in the corresponding cases of simple beams.

We now come to the fundamental theory of continuous girders known as the theorem of the Three Moments, with the load distributed in any manner whatever.

Let $x=o$, $y=o$ and $x=l$, $y=o$ be the co-ordinates of two adjacent points of support, x being taken horizontal. Let the vertical forces be positive downwards, at any point x between these two points of support let w be the intensity of the loading per unit of span, and EI as before the product of the modulus of elasticity and moment of inertia, all of which may be uniform or variable, continuous or discontinuous.

The following double and quadruple integrals will come in for which we will use the following symbols, viz.,

$$\int\int wdx^2=m, \int\int\frac{dx^2}{EI}=n, \int\int\frac{xdx^2}{EI}=q$$

$$\int\int\frac{dx^2}{EI}\int\int wdx^2=V.$$

Let the lower limit be $x=o$. When the integration extends over the whole

span, denote it by affixing 1 as n_1, q_1. Let $-$F be the upward shearing force near the point of support ($x=o$), M_0 the bending moment, and T the tangent of the inclination at the point of support. At any point x of the span, let M be the moment.

Now the sum of the moments of all the forces acting on the beam must be o $\therefore \Sigma(m_2)=$that sum$=o=M_0-F+M-M$.

$$\therefore M=M_0-Fx+m \qquad (6)$$

To find the deflection y, we have from the equation of the elastic line

$$\frac{d^2y}{dx^2}=\frac{1}{EI}M_0-\frac{1}{EI}Fx+\frac{1}{EI}m$$

integrating between o and x, we get—

$$\frac{dy}{dx}=M_0\int_o^x\frac{dx}{EI}-F\int_o^x\frac{xdx}{EI}+\int_o^x\frac{mdx}{EI}+T$$

integrating again—

$$y=M_0\int_o^x\int_o^x\frac{dx^2}{EI}-F\int_o^x\int_o^x\frac{xdx^2}{EI}$$
$$+\int_o^x\int_o^x\frac{mdx^2}{EI}+Tx$$

or using the symbols above given,

$$y=M_0n-Fq+v+Tx \qquad (7)$$

Now let M_1 be the moment at the farther end of the span, then substituting it for M in eq. (6),

$$F=\frac{M_0-M_1+m_1}{l} \qquad (8)$$

And since at the farther end $y_1=o$ (9)

$$T=\frac{Fq_1-m_0n_1-v_1}{l}=M_0\left\{\frac{q_1}{l^2}-\frac{n_1}{l}\right\}=\frac{M_1q_1}{l^2}$$
$$+\frac{m_1q_1}{l^2}-\frac{v_1}{l}.$$

Consider now an adjacent span extending from the origin ($x=o$) to $x=-i$ in the opposite direction to the first.

Let the definite integrals for this span be designated by affixing -1, as m_{-1}, n_{-1}. Let $-$T′ be the slope of this span at the point of support, then will be obtained just as before,

$$-T'={}_0\left\{\frac{q-1}{l'^2}-\frac{n_{-1}}{l'}\right\}-\frac{M_{-1}\,q_{-1}}{l'^2}$$
$$\frac{m_{-1}\,q_{-1}}{l'^2}-\frac{V_{-1}}{l'} \qquad (10)$$

Adding equations (9) and (10) and clearing of fractions, also denoting T$-$T′ by t the tangent of the angle made by the neutral layers when the continuity is not perfect, there will result,

$$0=M_0\,(q_1l'^2+q_{-1}\,l^2-n_1ll'^2)-n-{}_1l'l^2)-$$
$$M_1q_1l'^2-M_1q_1l'^2$$
$$-M_{-1}\,q_{-1}\,l^2+m_1q_1l'^2+m_{-1}\,q_{-1}\,l^2-V_1ll'^2$$
$$-V_{-1}\,l'l^2-tl^2l'^2 \qquad (11)$$

which is the general theorem of the three moments. As it is an eq. expressing the relation between the moments over three adjacent piers, M_0 being the moment over the pier at the origin, and M_1 and M_{-1} being the moments over the adjacent piers on the right and left.

A continuous girder of n spans has $(n-1)$ such equations and $(n-1)$ unknown moments, the moments at the endmost piers being zero, hence, we can by elimination, find the value of all these unknown moments. When the number of spans is large the elimination would be tedious in practice. But Clapeyron has introduced a system of multipliers called the Clapeyronian numbers which makes the elimination comparatively easy. They are such numbers that the eqs. when multiplied by them and added, all terms containing the moments disappear except one, which can be found directly, then by the same process the other moments can be found. Having found the moments, the inclination T can be found by eq. (9). The shearing force at the origin by eq. (8). The deflection by eq. (7) and the moment at any point in the span by eq. (6). The points of max moment can be found by solving the eq. $\frac{dm}{dx}=o$ and of max. deflection from the eq. $\frac{dy}{dx}=o$, and in the same way the other points of max. or min. change of any of the functions may be found.

(Ex. 2). The application of these formulæ to a continuous girder of any number of spans of equal lengths, alternate spans being heavily loaded *i. e.*, (bearing a load besides the weight of the bridge) will illustrate their use, $M=\frac{wx^2}{2}$; $n=\frac{x^2}{2EI}$, $q=\frac{x^3}{6EI}$ $V=\frac{wx^4}{24EI}$, EI being taken constant for the whole girder, $V=\frac{mq}{2x}$, for a complete span $x=l$, for heavily

loaded span $w=w_0+w_1$, lightly loaded $w=w_0$, n and q are the same for both heavily and lightly loaded spans. Noticing these points we now proceed to the solution of our eq. (11), and on account of similarity of circumstances over each pier, the moments over them all are equal or $M_0=M_1=M_{-1}$ and so for the others.

Reducing eq. (11), q_1 and q_{-1} cancel being taken between $+l$ and $-l$, and since $m_{11}=2V_1l$ and $mq_{-1}\,q_{-1}=2V_{-1}\,l$. The result is $0=-2M_0n_1+V_1+V_{-1}-tl$,

or $M_0=\frac{V_1+V_{-1}-tl}{2n_1}=$

$$\frac{\frac{(w_0+w_1)l^4}{24EI}+\frac{w_0l^4}{24EI}-tl}{\frac{l^2}{EI}}=\frac{(2w_0+w_1)l^2}{24}-+\frac{t}{l}EI$$

If now we suppose the girder *perfectly* continuous $t=o$ and $M_0=\frac{2w_0+w_1}{24}l^2$ (12). For simplicity t will be regarded as zero or the beam perfectly continuous in the remainder of the calculations.

The shearing force $F=\frac{M_0-M_1+m_1}{l}=\frac{m_1}{l}=\frac{w_0}{2}l$ or $(w_0+w_1)\frac{l}{2}$ for light and heavy loads. The slope $T=\frac{Fq_1-M_1n_1-V_1}{l}=\left\{\frac{w_0+w_1}{12EI}l^4-\frac{2w_0+w_1}{48EI}l^4-\frac{w_1+w_1}{24EI}l^4\right\}\div l=\frac{w_1l^3}{48EI}$, $-T^1=\left\{\frac{w_0l^4}{12EI}-\frac{2w_0+w_1}{48EI}l^4-\frac{w_0l^4}{24EI}\right\}\div l=-\frac{w_1l^3}{48EI}$ agreeing with the supposition $T+(-T^1)=t=\frac{w_1l^3}{48EI}+\left\{-\frac{w_1l^3}{48EI}\right\}=o$. Moment at any point in heavily loaded span $=M=M_0-Fx+m=\frac{2w_0+w_1}{24}l^2-\frac{w_0+w_1}{2}lx+\frac{w_0+w_1}{2}x^2$, $\frac{dM}{dx}=-\frac{w_0+w_1}{2}l+(w_0+w_1)x=ox=\frac{l}{2}$. The maximum moment is at the center; substituting this value of x in the equation of the moment, the max. moment $M=\frac{2w_0+w_1}{24}l^2-\frac{w_0+w_1}{4}l^2+\frac{w_0+w_1}{8}l^2=-\left\{\frac{w_0+2w_1}{24}\right\}l^2$.

For lightly loaded span $M=\frac{2w_0+w_1}{24}l^2-\frac{w_0lx}{2}+\frac{w_0x^2}{2}$, max. moment at the center$=\left\{\frac{w_1-w_0}{24}\right\}l^2$. The deflection $y=M_0n-Fq+V+Tx=\frac{2w_0+w_1}{48EI}l^2x^2-\frac{w_0+w_1}{2}l.\frac{x^3}{6EI}+\frac{w_0+w_1}{24EI}x^4+\frac{w_1l^3}{48EI}x$, $\frac{dy}{dx}=\frac{2w_0+w_1}{24EI}l^2x-\frac{w_0+w_1}{4EI}lx^2+\frac{w_0+w_1}{6EI}x^3+\frac{w_1l^3}{48EI}=o$, $x=\frac{l}{2}$ satisfies the eq. and we know from other conditions that the max. deflection is at the center, hence we need not discuss the cubic eq. but substituting $x=\frac{l}{2}$ in the value of y there is obtained the max. deflection for heavily loaded span. To find the same for lightly loaded span we have only to replace w_0+w_1 by w_0.

In this case we will apply the principle used in the first example for finding the moment over the piers to see if the two results agree. The actual moment$=M_1-M_1$, M being the moment were the beam free, and M_1 the constant moment over the piers. Take the origin at the center of the span, $c=\frac{l}{2}$. Let x be the abscissa of a heavily loaded span, and x' of a lightly loaded one.

$M=\frac{w_0+w_1}{2}(c^2-x^2)$ for heavy load, and $\frac{w_0}{2}(c^2-x'^2)$ for light load. ∴ The actual moment for heavy load$=M'=\frac{w_0+w_1}{2}(c^2-x^2)-M_1$, and for light $\frac{w_0}{2}(c^2-x'^2)-M_1$ slope $i=\int\frac{M'}{EI}dx=$ $\frac{1}{EI}\left\{\frac{w_0+w_1}{2}(c^2x-\frac{x'^3}{3})\ M_1x'\right\}$ (heavy) and $\frac{1}{EI}\left\{\frac{w_0}{2}(c^2x'-\frac{x^3}{3})-M_1x'\right\}$ for light load.

The beam being continuous i_1 for $x=c$ and $x=-c$, should be the same, equating the two values, we have

$$\frac{w_0+w_1}{2}(c^3-\frac{c^3}{3})-M_1c=-\frac{w_0}{2}c^3+\frac{w_0}{2}\frac{c^3}{3}+M_1c$$

or $\dfrac{2w_0+w_1}{3}c^3=2\mathrm{M}_1c$, $\mathrm{M}_1=\dfrac{2w_0+w_1}{6}c^2$

$$=\frac{2w_0+w_1}{24}l^2$$

which agrees with the value of M_1 obtained from the general formula. Points of inflection can be found by solving $\dfrac{d^2y}{dx^2}=o$ or ∞, or by means of the equation $\mathrm{M}-\mathrm{M}=o$, in either case there will result a quadratic equation giving two points in each span.

(Ex. 3)

$\mathrm{A}_0 \quad \mathrm{A}_1 \quad \mathrm{A}_2 \quad \mathrm{A}_{n-2} \quad \mathrm{A}_{n-1} \quad \mathrm{A}_n$

$a_1 \quad a_2 \quad a_{n-1} \quad a_n$

$\mathrm{Q}_0 \quad \mathrm{Q}_1 \quad \mathrm{Q}_2 \quad \mathrm{Q}_{n-2} \quad \mathrm{Q}_{n-1} \quad \mathrm{Q}_n$

Let $\mathrm{A}_0\mathrm{A}_n$ be a continuous girder, $\mathrm{A}_0\mathrm{A}_1$ etc., points of support or subject to the action of isolated loads, $\mathrm{Q}_0\mathrm{Q}_1$ etc., positive upward action of piers or negative downward action of loads. Consider a section normal to the elastic curve in the span $\mathrm{A}_{n-1}\,\mathrm{A}_{n-1}$ $a_1\ a_2\ldots$ the lengths of the divisions $\beta_0\ \beta_1\ldots$ the angles made by the girder at the piers with the horizontal line, w the intensity of the loading. Then the eq. of the elastic line $\mathrm{EI}\,\dfrac{d^2y}{dx^2}=\mathrm{M}$ becomes $\mathrm{EI}\,\dfrac{d^2y}{dx^2}=\frac{1}{2}\,(a_1+a_2+\ldots.+a_{n-1}+x)^2w-(a_1+a_2+\ldots+a_{n-1}+x)\,\mathrm{Q}_0-(a_2+a_3\ldots+a_{n-1}+x)\,\mathrm{Q}_1-\ldots\ldots-(a_{n-1}+x)\,\mathrm{Q}_{n-2}-x\mathrm{Q}_{n-1}$, x being the distance of the section from A_{n-1}; reducing these results,

$$\mathrm{EI}\frac{d^2y}{dx^2}=\tfrac{1}{2}\,(a_1+a_2+\ldots.+a_{n-1})^2w+(a_1+a_2+\ldots+a_{n-1})\,wx+\tfrac{1}{2}wx^2-a_1\mathrm{Q}_0-a_2(\mathrm{Q}_0+\mathrm{Q}_1)-a_3(\mathrm{Q}_0+\mathrm{Q}_1+\mathrm{Q}_2)-\ldots\ldots.-a_{n-1}(\mathrm{Q}_0+\mathrm{Q}_1+\ldots+\mathrm{Q}_{n-2})-x(\mathrm{Q}_0+\mathrm{Q}_1+\ldots\mathrm{Q}_{n-1}).$$

Integrating $\mathrm{EI}\left\{\dfrac{dy}{dx}-\tan.\beta_{n-1}\right\}=\frac{1}{2}\,(a_1+a_2\ldots+a_{n-1})^2wx+\frac{1}{2}\,(a_1+a+_2+\ldots+a_{n-1})wx^2+\frac{1}{6}\,wx^3-[a_1\mathrm{Q}_0+a_2\,(\mathrm{Q}_0+\mathrm{Q}_1)+a_3(\mathrm{Q}_0+\mathrm{Q}_1+\mathrm{Q}_2)+\ldots.+a_{n-1}\,(\mathrm{Q}_0+\mathrm{Q}_1+\mathrm{Q}_2+\ldots.+\mathrm{Q}_{n-2})]x-\frac{1}{2}(\mathrm{Q}_0+\mathrm{Q}_1\ldots.+\mathrm{Q}_{n-1})x^2.$

Integrating again and noting that when $x=o$, $y=y_{n-1}$, there results

$\mathrm{EI}(y-y_{n-1}-\tan.\beta_{n-1}x)=\frac{1}{4}(a_1+a_2+\ldots+a_{n-1})^2wx^2+\frac{1}{6}(a_1+a_2+\ldots+a_{n-1})wx^3+\frac{1}{24}wx^4-\frac{1}{2}[a_1\mathrm{Q}_0+a_2\,(\mathrm{Q}_0+\mathrm{Q}_1)+a_3(\mathrm{Q}_0+\mathrm{Q}_1)+\mathrm{Q}_2)+\ldots.+a_{n-1}(\mathrm{Q}_0+\mathrm{Q}_1+\mathrm{Q}_2+\ldots.+\mathrm{Q}_{n-2})]x^2-\frac{1}{6}(\mathrm{Q}_0+\mathrm{Q}_1x\ \ldots.\ x\mathrm{Q}_{n-1})x^3.$

The integral equation of the elastic line between A_{n-1} and A_n in the last two equations, making $x=a_n$, $y=y_n$, and $\dfrac{dy}{dx}=\tan.\beta_n$, they become

$\mathrm{EI}(\tan.\beta_n-\tan.\beta_{n-1})=\frac{1}{2}(a_1+a_2+\ldots.+a_{n-1})^2wa_n+\frac{1}{2}(a_1+a_2+\ \ldots.\ +a_{n-1})\,w\,a^2_n+\frac{1}{6}wa^3_n-[a_1\mathrm{Q}_0+a_2\,(\mathrm{Q}_0+\mathrm{Q}_1)+a_3\,(\mathrm{Q}_0+\mathrm{Q}_1+\mathrm{Q}_2)+\ \ldots.\ +a_{n-1}(\mathrm{Q}_0+\mathrm{Q}_1+\mathrm{Q}_2+\ \ldots\ +\mathrm{Q}_{n-2})]a_n-\frac{1}{2}(\mathrm{Q}_0+\mathrm{Q}_1+\ldots+\mathrm{Q}_{n-1})a^2_n$. The last one becomes $\mathrm{EI}\left\{\dfrac{y_n-y_{n-1}}{a_n}-\tan.\beta_{n-1}\right\}=\frac{1}{4}(a_1+a_2+\ \ldots+a_{n-1})^2wa_n+\frac{1}{6}(a_1+a_2+\ldots+a_{n-1})wa^2_n+\frac{1}{24}\,wa^3_n-\frac{1}{2}\,[a_1\,\mathrm{Q}_0+a_2\,(\mathrm{Q}_0+\mathrm{Q}_1)+a_3\,(\mathrm{Q}_0+\mathrm{Q}_1+\mathrm{Q}_2)+\ \ldots..\ +a_{n-1}(\mathrm{Q}_0+\mathrm{Q}_1+\mathrm{Q}_2+\ \ldots.\ +\mathrm{Q}_{n-2}]a_n-\frac{1}{6}(\mathrm{Q}_0+\mathrm{Q}_1+\mathrm{Q}_2+\ldots.\ +\mathrm{Q}_{n-1})a^2_n.$

These equations taken in conjunction with the two general equations of equilibrium given below are sufficient to solve the problem, $(a_1+a_2+a_3+\ \ldots.)w=\mathrm{Q}_0+\mathrm{Q}_1+\mathrm{Q}_2+\ldots$ and $a_1\mathrm{Q}_0+a_2(\mathrm{Q}_0+\mathrm{Q}_1)+a_3(\mathrm{Q}_0+\mathrm{Q}_1+\mathrm{Q}_2)+\ \ldots.\ =\frac{1}{2}\,(a_1+a_2+a_3+\ldots..)^2w$, being the general equations. The eqs. deduced are true for all indices $n=1$, 2, 3, &c. This method of treatment is the one given by Scheffler; it first becomes applicable when the number of spans exceeds three. The number of equations for any example may be reduced one half when the conditions on each side of the center of the girder are identical. If the points of support and isolated loaded points are in the same horizontal line y_n, y_{n-1}, &c., disappear.

The method of using and determining the Clapeyronian numbers will now be given. These numbers play an important part in the solution of continuous girders. Let the number of moments be $(n+1)$, the moments at the two abutments M and M_{n+1} equal zero. The equations involve these moments and constants, depending upon the length of the spans, intensity and distribution of the loading, they will be of the type

$$\left.\begin{array}{l} a_1\mathrm{M}_2+b_1\mathrm{M}_3=\mathrm{A}_1 \\ a_2\mathrm{M}_2+b_2\mathrm{M}_3+d_2\mathrm{M}_4=\mathrm{A}_2 \\ a_3\mathrm{M}_3+b_3\mathrm{M}_4+d_3\mathrm{M}_5=\mathrm{A}_3 \\ \ldots\ldots\ldots\ldots\ldots=\ldots \\ a_{n-1}\,\mathrm{M}_{n-1}+b_{n-1}\,\mathrm{M}_n=\mathrm{A}_{n-1}. \end{array}\right\}$$

Multiplying the first by c_2, the second by c_3 and so on, we will get,

$$a_1c_2M_2+b_1c_2M_3=c_2A_1$$
$$a_2c_3M_2+b_2c_3M_3+d_2c_3M_4=c_3A_2$$
$$a_3c_4M_3+b_3c_4M_4+d_3c_4M_5=c_4A_3$$
$$\ldots\ldots\ldots\ldots=\ldots$$
$$a_{n-1}c_n M_{n-1} + b_{n-1}c_n M_n = c_n A_{n-1}$$

Adding these equations we get

$$(a_1c_2+a_2c_3)M_2+(b_1c_2+b_2c_3+a_3c_4)M_3+(d_2c_3+b_3c_4+\ldots)M_4+\ldots\ldots+(\ldots+b_{n-1}c_n)M_n=A_1c_2+A_2c_3+\ldots+c_nA_{n-1}$$

This equation involves all the moments with only known and arbitrary constants. These are arbitrary constants; c_2, c_3, c_4 &c., which are the Clapeyronian numbers, may be so chosen as to make the coefficients of all the moments disappear except one, which will then be known. In the same way the other moments may be obtained. By placing the coefficients of the moments we wish to disappear equal to zero, the relation between the Clapeyronian numbers is easily seen.

ON A NEW DYNAMOMETER FOR LOCOMOTIVES.

By H. KILLICHES.

From "Die Eisenbahn," Abstracts published by the Institution of Civil Engineers.

This dynamometer is intended to answer the same purpose for locomotives as the friction brake dynamometer for ordinary engines. The instrument is fixed between the engine and the first carriage and records, by means of a pointer moving over a face like that of a gas meter, the number of hectometer-tonnes performed by the engine in any given time. For this purpose the revolutions of one pair of wheels are measured by means of a worm fixed on the axle, engaging with a small worm wheel which is mounted on a long spindle reaching from the axle to the recording apparatus between the engine and the carriage. Here the motion is transferred, by means of a pair of bevel wheels, to another small shaft, which carries a large disk. Against the face of this disk presses a small wheel, connected with a spiral spring, which through a system of levers, is extended by and in proportion to the strain on the draw-bar. When this strain is zero, the wheels rest exactly on the center of the disk; but when the strain has any other value, the wheel is pushed outward towards the circumference of the disk through a proportionate distance and it then revolves by friction with the same velocity as the portion of the disk at that particular distance from the center. Thus, it will be seen that when the speed of the axle is constant, the revolutions of the small wheel are proportional to the pull on the draw-bar, and when the pull is constant; the revolutions of the small wheel are proportional to the speed of the axle or to the distance run by the train; therefore, when both vary, the revolutions of the small wheel are proportional to the product of these two (the pull on the drawbar and the distance run by the train), *i. e.*, in other words, to the work done by the engine. All that remains is to connect this wheel to the pointer by a train of clock-work, and the latter will then record the work done. Various devices and precautious are described for rendering the principle efficient, and an account is given of experiments made with the apparatus on the Archduke Albert railway, in Austria. It was found, for instance, that the greatest variations in the resistance to traction took place in April and May, on account of the changeable weather; and, again, that the traction was less towards evening, because the weather is then generally finer, and there is less wind. The apparatus applied, either to ascertain the average work done during a long trip, or the total work at some special part of the line. In the latter case, the record must be noted at short intervals, and the speed observed independently. The following important points, among others, may be determined by the use of this dynamometer :

1. The actual power of an engine, and the proportional consumption of fuel may now, for the first time, be accurately ascertained.

2. The tables of maximum load on inclines, &c., may be corrected and verified. The maximum loads should be varied according to the season of the year, by an amount which will be fixed by the use of the dynamometer.

3. In cases where trains are delayed, &c., the dynamometer will show whether this was due to an increase in the tractive force or to the fault of those in charge of the train.

4. It enables the amount of fuel consumed, in proportion to the work done, to be accurately known, and the prizes for economy given to the drivers to be placed on a rational basis. It must, of course be remembered that it does not give the work done in moving the engine itself, but this can be easily ascertained by other means, and is not subject to much variation from differences of wind and weather.

THE USE OF ZINC IN STEAM BOILERS.

From "Engineering."

The employment of zinc in steam boilers, like that of soda, has been adopted for two distinct objects, (1) to prevent corrosion, and (2) to prevent and remove incrustation. To attain the first object it has been used chiefly in marine boilers, and for the second chiefly in boilers fed with fresh water. We purpose dealing with each head separately in the above order, and in as popular a manner as the subject will allow.

The suggestion to use zinc for the protection of the copper sheathing of vessels by Sir H. Davy, and his development of this principle in 1824, appears to have suggested to Professor E. Davy, about ten years later, the application of zinc for the protection of the iron buoys in Kingstown Harbor. This is probably the first application of the principle to protect iron against the corrosive agency in sea-water. The application of the same principle to protect the interior of steam boilers against corrosion does not appear to have been attempted before the year 1850. It was not, however, till the introduction of surface condensation for marine engines that zinc can be said to have been extensively used to prevent the corrosion of the iron plates and tubes, which were no longer protected to the same extent by the scale that formed upon them when jet condensers were used.

Zinc has been applied in various ways in marine boilers, viz., by suspending it in plates of various size and number from the stays, and more rarely amongst the tubes where practicable. The zinc plates or bars have been placed in boxes in various parts of the boiler, sometimes for the feed to pass through, and in other cases the zinc has been arranged for the feed to deliver upon it as it enters the boiler. As may be imagined, these various ways of applying the zinc led to very different results. In a great many cases its use was not attended with any apparent advantage, and it was consequently discontinued. In other cases, however, where its application had been made in a more judicious manner, it was more successful, and its use has been continued with very favorable results up to the present time.

It is evident, from the manner in which zinc has been employed in the great majority of cases to prevent corrosion, that the principle of its action has been assumed to be simply chemical; that it had a greater affinity than the iron for the oxygen and acids in the water. In order that this supposed simple chemical action should take place efficiently, and that the corrosive agents throughout the whole body of water should be neutralized, it would be necessary that they should all be brought in contact with the zinc before they could come in contact with the plates and tubes. Were the zinc soluble in water, this condition might be carried out, but as zinc is not soluble, and cannot reach all the corrosive ingredients in solution, or held in

suspension and diffused throughout the water, it follows that all the particles of water must be brought and kept in contact with the zinc for a time in order that it may be really efficacious. That this is likely to take place in a large boiler with a few pieces of zinc cannot be maintained. Were the simple chemical action alone relied upon for the protective action of the zinc, the plates and tubes should be nearly covered with it in order that this action should be effective, since the iron would share with the zinc the corrosive action of the water, in proportion to the surface of each metal exposed. We must then look for some other explanation of the success which has attended the introduction of a few bars of zinc into a large boiler.

The remarkable protection that zinc has afforded in many authenticated cases, can only be explained by ascribing it to galvanic action. When a metal like iron, which is acted upon more or less by a liquid, is brought into contact with another metal like zinc, which has a much stronger affinity for the oxygen of the liquid, or for the acids of the salts contained in solution, the zinc or positive electrode is dissolved and imparts a negative tendency to the iron, which preserves it by preventing the oxygen or acids from acting upon it. In most cases where zinc is employed with advantage to prevent corrosion in boilers, the water is a weak solution of salts. This solution is decomposed by the galvanic current in such a manner that the oxygen and acids are liberated at the positive pole (+zinc), and the hydrogen of the water and metal of the salt at the negative pole (−iron). The decomposition of the water, or electrolysis as it is called, takes place in such a manner that the oxygen of one molecule of water in contact with the zinc is separated, and the liberated hydrogen combines with the oxygen of a neighboring molecule, whose oxygen in its turn combines with the hydrogen of the next molecule, and so the action goes on till the hydrogen of the water in contact with the iron at a considerable distance is liberated, without the hydrogen and oxygen having to cross the water as free gases. It is in consequence of this action that a piece of zinc placed in the middle of a plate of iron has the valuable property of exercising a protective influence over a large surface of which it is the center. The extent of the range of its action will depend upon the purity of the zinc, the nature of the salts in solution, the temperature of the water, and the condition of the surfaces of the zinc and iron. In order that the protective action may take place effectively, it is necessary that the zinc and iron should be in perfect metallic contact. It is extremely probable that the fulfillment or not of this last condition has determined the efficacy or non-efficacy of the application of zinc in the numerous cases where it has been tried with such different degrees of success. Zinc "bottoms" should not be used, nor indeed is some of the spelter in the market sufficiently pure to act to the best advantage. But, as a rule, good commercial English or Belgian zinc may be considered as being sufficient for the purpose. A high temperature is favorable for the setting up of the galvanic current, and therefore for the protection afforded by the zinc.

Besides having the zinc and iron in perfect metallic contact, it is necessary for the maintenance of the galvanic current, upon which the success of the application of the zinc depends, that the surface of the zinc exposed to the water should be kept clean and free from any non-conducting coating that may be formed by the chemical action that ensues on the liberation of the oxygen and acids at the surface of the zinc. This brings us to a very important consideration that is liable to be overlooked.

When the oxygen and acids are set free at the surface of the zinc, oxide of zinc is formed, and this combines with the acids to form salts. These salts are either soluble or insoluble in the water. If soluble they become diffused through the water, the zinc is kept clean, and the galvanic action is sustained at the expense of the zinc. If insoluble the salts tend to collect upon the zinc, which in time becomes coated with them. As this coating is a non-conductor, the galvanic action is gradually arrested, and, in time, ceases altogether, the presence of the zinc being consequently no longer efficacious.

With sea-water the sulphuric and hydrochloric acids liberated from the contained sulphates and chlorides, com-

bine with the oxide of zinc, and from sulphate and chloride of zinc, which are very soluble, hence the successful application of zinc in marine boilers. But in boilers fed with fresh water where the acids liberated are too small in quantity to combine with all the oxide of zinc to form soluble salts, the film of oxide that forms on the surface of the zinc, in time, puts an end to its useful effect.

It is well known that the galvanic current has no effect on the oxygen in solution in the water, and that it is only the oxygen chemically combined with the hydrogen in the water, and in the bases of the salts, that are liberated at the surface of the zinc. The question then arises, how can the zinc protect the iron from the oxygen in solution in the water which may be in contact with the plates? The answer is, by a secondary and chemical process, viz., the hydrogen liberated at the surface of the iron combines with the oxygen in solution and forms water, or the metals liberated from the salts at the surface of the iron unite with this free oxygen and form bases. In fact these metals have such an affinity for oxygen that they attract it from the water and residuary hydrogen is evolved.

We have been led to this length in explaining the principles upon which the success or non-success of zinc depends, as it is likely to be largely employed since the Admiralty Boiler Committee have spoken so strongly in favor of the use of zinc for preventing corrosion. The portions of the Boiler Committee's report treating of the use of zinc, are very valuable, and we shall deal with them in a future article, when we shall also have something to say on the use of zinc for preventing incrustation.

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—At the recent annual meeting the following persons were elected officers of the American Society of Civil Engineers for the year beginning November 6th, 1878: *President*—W. Milnor Roberts; *Vice-Presidents*—Albert Fink, James B. Francis; *Secretary*—John Bogart; *Treasurer*—J. J. R. Croes; *Directors*—George S. Greene, William H. Paine, C. Vandervoort Smith, T. C. Clarke, Theo. G. Ellis.

ENGINEERS' CLUB OF PHILADELPHIA.—At the last meeting of the Club, Professor Lewis M. Haupt, President, read a paper on "The Scales of Maps and Drawings," giving some simple rules for the removing of ambiguities at present existing. It is evidently incorrect to indicate the scale of a map as so many inches to the mile, or of a drawing, as so many feet to the inch, when the intention is a certain number of miles or feet to the inch of paper. The paper also referred to the great number of scales in use, and the great inconvenience caused thereby, urged the necessity for some measures which should reduce or overcome this defect, and closed by presenting two tables of map equivalents, showing the number of miles, kilometers, chains, poles, meters, yards and feet which are equal to one inch of map, for any scale, and reciprocally the number of square inches of map required to represent one or more units of the above denominations.

Mr. I. W. Morris read a letter from Mr. C. F. Conrad, which gave the following interesting information in regard to the "Butler Mine Fire Cut-off:"

"Before locating the line of the cut-off, I learned of the first fire which they had in the same vein (14 feet thick) in 1856-57, and after careful inquiry learned its position and made my location for the through cut to pass as near as possible through the center of the "old fire." This was done, hoping to find all combustible matter, coal, "gob" and carbonaceous slate burnt to ashes, in which case it would have saved many thousand yards of excavation, as it would have presented an impassable barrier to the progress of the present fire.

This cut-off afforded an opportunity rarely, if ever, equalled to learn truly and fully the work of a fire in a coal mine. It was found the slate above and surrounding the coal and all the "gobb" was burned either to ashes or into slag, resembling ordinary furnace slag, while the pillars of solid coal were perfectly sound and bright. About the middle of the 14-feet vein of coal is an 8-inch line of slate, and this was found burned to a white ash, while the coal above and below were perfectly bright. When the fire reached the end of the workings it made no further progress, but, after burning the fallen rock to ashes or slag, it entered the face of the coal two or three inches and then went out.

Mr. Conrad concludes by saying that he is led to believe that solid coal cannot be burnt in place; that slate rock found in coal veins contains more gas than the coal; that fires in coal mines are fed and live on the "gob" (refuse slate, &c.), and gases, and that "gob" is an excellent reservoir for gas. Ventilation will carry off free gas, but "gob" holds gas as a sponge does water.

Mr. Edward R. Andrews, of Boston, proprietor of the Hayford Creosote Wood Preserving Works, gave a full description of the apparatus employed in his process and of the results obtained by the use of creosoted wood. Decay in wood is due primarily to the fermentation of the albumen of the sap, which commences as soon as the necessary conditions, heat and moisture, are supplied. The aim of all wood preservatives has been to overcome this fermentation by coagulating the albumen. Experiments to produce this result were made as early as 1700.

Bethel, 1837, introduced dead oils as wood preservatives, and to show the success which has attended this process, it is only necessary to state that it is used by every railway in England, where nearly all timbers used in construction are impregnated with creosote. The Hayford process differs from that of Bethel in this particular; the latter can only be applied to seasoned timber, while in the former process timber can be taken as it comes from the saw mill and creosoted in a few hours.

The cost of creosoting railroad ties is from 25 to 30 cents per tie. Paving blocks have recently been treated for the Broadway Bridge, Boston at a cost of $12 per thousand feet, cord measure.

A section of a railroad tie was shown which had been in use in Scotland for over twenty years, and seemed to be in perfect condition; the rail has not cut it, and there are no signs of rot in the spike holes. There is every reason for believing that creosoted ties will last here for twenty years as well as in Europe Already several railroads are using them. In 1875 the Central Railroad of New Jersey laid ten thousand creosoted ties near Bound Brook, which, thus far, show no signs of decay.

In addition to protecting from decay, creosoting is equally a specific against destruction of wood by marine worms. Experiments are being tried on ship timber in the U. S. steamer Vandalia, now in the Mediterranean. This vessel was built at the navy yard in Charleston during 1872. All the timber except the live oak ribs, both inside and out, were creosoted by the Hayford process. The vessel went to sea in 1874, and is expected home next year, when the result of the experiment will be known.

When we take into consideration the enormous drain which is being made on our supply of timber, stripping the forests altogether from many parts of our country, it would seem that we ought to be alive to the importance of preserving timber.

Mr. Percival Roberts, Jr., read a very able paper on the "Strength of wrought iron in structures." He called attention to the great need for more accurate knowledge in regard to the strength of wrought iron, and criticised, in a terse and interesting manner, some of the testing machines and specifications of the present day.

IRON AND STEEL NOTES.

In speaking of the Birmingham wire gauge, the warden of the Standards in his last report says that there is no standard wire gauge, or common agreement amongst those interested as to what are the dimensions in parts of an inch of the several slots or sizes of the true B.W.G. Its sizes are not geometrically or arithmetically progressive, and consequently bear no definite relation to each other. Its origin is obscure, and it would appear that the several slots or sizes arose from time to time as a new wire or a new plate was introduced, and as the exigencies of a particular trade demanded. In Germany, gauges for wire or sheet iron have not yet been officially controlled. The Birmingham gauge, commonly called the "English gauge," is mostly in use in Northern Germany for measuring sheet iron, wire, and hoop iron. In Southern Germany, the B.W.G. is also used, and for the measurement of wires the French gauge, which is a progressive scale of tenths of a millimeter (1 millimeter= 0.0393709 inch) is also used. For sheet iron the "Dillingen gauge," which is a scale of Paris lines (1 line=0.08881377 inch) is also used in Southern Germany. The wire factories in Westphalia use a particular gauge called the "Bergish, or Westphalian." For some time past the question of establishing a uniform wire gauge and a uniform numbering of wires has been energetically agitated in Germany. The manufacturers in Russia use different gauges of English, German and French patterns. In Canada only one gauge is known to mechanics—the Birmingham wire gauge—made by Stubbs, of Warrington. In France measurements are made by the scale of one-tenth of a millimeter as well as by the Birmingham and Dillingen arbitrary guages. In America the B.W.G. is extensively used, but a special committee recently recommended the expression sizes in thousandths of an inch, or in fractions of a millimeter. An international standard gauge is much wanted. Meanwhile, it should be remembered that in any contract, bargain, sale, or dealing, the sizes of wire and metal plates are legally expressed only in Imperial measures or in parts of an inch.

Different Qualities of Iron and Steel.—By C. Grauhan.—The Author describes at full length the characteristics of the different species of steel and iron. Of steels he mentions puddled, Bessemer, Martin, and cast steel, pointing out that generally the first has the coarsest and the last the finest grain; puddled steel generally shows some traces of having been formed of several pieces, while Bessemer and the other qualities, being cast in blocks, are homogeneous. But Bessemer metal is frequently porous, and when worked up for railway axles or similar purposes, the bubbles are first closed by forging, but show themselves again in the form of longitudinal cracks when taken out of the lathe. These bubbles occur seldom in Martin steel, never in cast steel. And a further difference between Martin and Bessemer steel is, that the former contains less silica.

According to the Author, the quality of steel cannot be fairly tested unless it is first hardened, as otherwise a bar which was rolled rather hotter than another would show quite a different texture, although of the same metal. The steel should be heated, forged to bars of a uniform size, and then hardened in water, which process eliminates any chance differences. If a bar thus prepared be broken, the texture, color, and general appearance of the fracture will give a very close approximation to the quality. Of course, although fine-grained steel is better than coarse grained, the former cannot be used for every purpose. Rails and axles, for instance, require coarse-grained, porous, and soft metal. If after sudden im-

mersion in water the grain is as coarse as before, the steel is not fit for hardening and approximates to wrought iron. The finer the grain the harder is the metal and the more carbon does it contain. If the fracture shows a coarse grain and a whitish reflection there is a good deal of phosphorus and silica in the steel, which is, of course, injurious. If it shines blue instead of white the metal is burnt and contains too little carbon.

As a rule, the hardness of steel depends on the amount of carbon it contains, and the quantity of carbon resulting from analysis is used as a measure of its hardness.

Herr Grauhan mentions the different methods of testing iron, of which he prefers the chemical mode, and gives the following results of the analyses of various sorts of iron :

1. WESTPHALIAN BESSEMER IRON.

	Per cent.
Iron	86.912
Carbon	3.200
Silicium	3.140
Manganese	6.180
Phosphorus	0.120
Sulphur	0.070
Copper	0.380

2. WELSH IRON (WHITE).

Iron	94.400
Carbon	2.400
Silicium	0.800
Sulphur	0.700
Phosphorus	1.500
Manganese	0.200

3. SPIEGEL IRON FROM MUSEN.

Iron	82.860
Carbon	4.323
Silicium	0.997
Manganese	10.707
Phosphorus	0.059
Sulphur	0.014
Copper	0.066

4. BESSEMER RAIL FROM A WESTPHALIAN WORKS, WHICH BROKE IN UNLOADING.

Carbon	0.370
Manganese	0.650
Silicium	0.223
Sulphur	0.040
Phosphorus	0.084

5. CAST-STEEL AXLE FROM A WESTPHALIAN WORKS.

Carbon	0.221
Silicium	0.061
Phosphorus	0.052
Sulphur	0.072
Manganese	0.276
Copper	0.072

6. RETORT-STEEL TIRE OF A WESTPHALIAN WORKS.

Carbon	0.5800
Sulphur	0.0380
Silicium	0.1010
Phosphorus	0.0407
Manganese	0.6080

N.B.—The tenacity of this tire was 71 to 74 kilogrammes per millimeter, or about 43 tons to the square inch.—*Abstracts of Institution of Civil Engineers.*

CHROMIUM augments the hardness and tensile resistance of iron alloys; but it has no "steelifying" properties, and cannot take the place of carbon. Boussingault fused chromic oxide with cast iron in such proportions as to burn all the carbon of the latter with the oxygen of the former; but the non-carboniferous alloy of iron and chromium thus obtained would not temper. Berthier is the real discoverer of the acier chrome, or chromised steel. As long ago as 1821, he indicated the means of introducing chromium into cast steel, and announced that the compound thus formed possessed properties which might render it precious for many purposes. It is now manufactured, says M. Rolland in his "Note sur l'Acier Chrome," just published in Paris; at Brooklyn, N.Y.; Sheffield, England; and in France at Unieux, in the department of the Loire. A sample of ferro-chrome from Brooklyn, analysed by Boussingault, showed 4.29 per cent. of combined carbon and 48.70 of chromium. The ferro-chrome of Unieux contains about 5.4 per cent. of combined carbon and up to 67.2 per cent. of chromium. Chrome steel is made at Unieux, as at Brooklyn, by fusing in crucibles, in a Siemens furnace, fragments of wrought iron or steel of the first quality, with an addition of ferro-chrome calculated for the degree of acieration and hardness required. The steels of Unieux vary in their contents of chromium from 0.5 to 0.9 per cent. Boussingault found in a hard steel from Brooklyn 1.1 per cent. of combined carbon and 0.44 of chromium. Concerning the properties of chrome steel, and the peculiar manipulation required in working and tempering it, M. Rolland gives substantially the same statements as the circulars of the Chrome Steel Company, of Brooklyn. The directions may be summed up in two : For working—except punching, which may be done, it is said, at a moderate temperature—the heat should be high—nearly white at first; for tempering and hardening, a low cherry heat is the best. M. Rolland says, in conclusion, that chrome steel is as yet but little known, and much restricted in its applications.

RAILWAY NOTES.

MR. A. C. FRANKLIN, of Brighton, is bringing out a tram-car motor in which a central wheel is used for propulsion on the common road, no reliance being placed upon the adhesion of the wheels upon the rails. Compressed air is to be employed in long cylinders, in which pistons reciprocate and work racks geared upon pinions upon the driving wheel axle, arrangements being made for producing revolution in one or both directions, whichever way the pistons are moving. Some practical trials will probably be made.

THE employment of wheels larger than those commonly used on American stock has lately occupied much attention. A trial having been made of the value of 33 inch and 42 inch car wheels upon long-distance express trains, the Boston and Albany Railway is preparing to place the larger size under all its New York through passenger cars. The life of the usual

cast iron 33 inch wheel on these long running trains is about four years, but of late the steel-tired wheel has been run a very much longer time. The new wheels will be of the steel-tire pattern, and made by a Hartford, Conn., company, and the change in all its incidentals will involve an outlay of over £5000. The superintendent expects to secure not only a stronger wheel but one less liable to catch at the joints and pound the rail ends, much less friction in the journals, and less danger from hot boxes.

"To whom are we indebted for the Railway Ticket System," is the title of a small pamphlet, in which Mr. J. B. Edmonson gives an account of the origin, invention, and rise of the railway ticket system, as now adopted by almost every railway company throughout the world. The invention and system are due to the labors of one Thomas Edmonson, who was born in 1792, became connected with railways in 1844, and seeing the disadvantage connected with the paper voucher written and supplied to passengers, contrived a rude method of printing cards, arrangements for numbering them, and cases in which the tickets thus made could be arranged and kept for issue. The printing apparatus was at first very crude, but the arrangement of the ticket cases and tubes are now very much the same as when Edmonson contrived them. He subsequently designed very complete machinery for printing, numbering, and checking the numbers of the tickets, and designed arrangements of color and number for purposes of checking the receipts. The pamphlet is published by H. Blacklock & Co., Manchester.

Some interesting information is conveyed by the recent report of the Board of Trade on the railways of the United Kingdom during 1877. These reports are not usually very attractive reading, but having overcome one's mental inertia, we are enabled to learn from them something that is not the less useful because it is somewhat discomforting. With all our railway improvements, our working expenses grow rather than decrease, though a few lines must be excepted. Thus in 1870 the maintenance of way cost 5.89d. per train mile, in 1877 this was increased by 1.63d., locomotive power cost 1.07d. more, traffic expenses 2.24d., and other items 0.86d. more. The ratio of expenditure to traffic receipts, though rather less than in 1876, was 54.1 per cent. For the last five years the proportions have been: 1873, 54 per cent.; 1874, 55.6 per cent.; 1875, 54.6 per cent.; 1876, 54.2 per cent.; and 1877, 54.1 per cent. In 1870 it was but 48.8 per cent. Now as the difference of a penny per train mile amounts to about a million sterling, and of 1 per cent. in the proportion of expenditure to receipts, to about £600,000, there would be an enormous addition to the net earnings of the companies if they could get back to anything like the working expenses of 1870.

Railways are in course of construction in Russia in Asia. Contractors' trains are now, it is said, running over the Ural Mountains to the city of Ekaterinereburg, just on the Asiatic side. This place is in about latitude 57 and in longitude 60 deg. east of Greenwich, that is, about 100 miles further north and 800 miles further east than Moscow—as far north as Aberdeen and as far east as the head of the Indian Ocean. There is now on the Eastern Continent a continuous line of railroad from longitude 10 west to 60 degrees east of Greenwich, the western terminus being south of latitude 40, and the eastern about latitude 57. This exceeds the extent of the North American system from about 46 west of Greenwich—Halifax—to 105 west—San Francisco. The European system covers 70, the North American 59 degrees of longitude. The railroad enters Ekaterinereburg from Perm, which is about 190 miles north-west, by a high level line, and in that inland and elevated district must have a very severe winter. It is not quite so far north as St. Petersburg and the Finland railroads, but the latter have the winters somewhat modified by the nearness of the Baltic Sea; while Perm has no sea nearer than 800 miles, and that is the arctic, and the Ural range is close by. The road from Perm to Ekaterinereburg, 310 miles, was to be opened to the public September 1st, and a good deal of work has been done on an extension of the road into Siberia.

The final result of English railway working in 1877 may be stated as follows: The extent of the system increased 1.2 per cent., the double mileage 0.7 per cent. The capital increased 2.4 per cent., and the capital per mile open increased 1.2 per cent. The ordinary capital increased more slowly than the total capital, or only 1.2 per cent. The gross receipts increased 1.2 per cent., or rather less than the rate of increase of capital; but the working expenditure increased only 1.0 per cent. so that the increase of net earnings is 1.5 per cent. The receipts, expenditure, and net earnings per train mile have all decreased slightly. The result is (1) a slight diminution of the percentage of net earnings on the whole capital, viz., from 4.36 to 4.32 per cent., and (2) a slight diminution of the dividend paid on the ordinary capital, viz., from 4.52 to 4.51 per cent. These are the results in a year in which the increase of traffic was at a lower rate than at any time since 1858, the average rate having been in that period 4.65 per cent., while last year it was only 1.21 per cent. They are also the results at a time when the rate of working expenses is at a high level compared with the whole period prior to 1872. The result to railway capitalists cannot be deemed unfavorable, though the average is composed in part of some unfavorable extremes. As regards the public use of railways, the increase of third-class traffic, as well as of minerals and goods conveyed, would appear to show that that use has been increased in 1877 in a greater degree than the return to the owners of the railway system.—*Engineer.*

The use of chilled cast iron wheels is, according to a correspondent of the *American Railroad Gazette,* slowly but steadily getting into favor in Europe, especially on the Austro-Hungarian railroads, which have for many years been using them with the best results. In the year 1844, Mr. A. Ganz, a Swiss citizen, established in Buda a foundry; and in 1854,

being induced by some railroad engineers, he began to experiment in chilling cast iron; and, having on hand Hungarian ores of superior quality, he was able, in 1857, to execute some important orders for chilled wheels for the Austrian and Hungarian railroads. The highest number of wheels produced by this establishment in a year was 36,000, in the year 1872; but owing to the industrial crisis of 1873 it has fallen off, and only during the last two years has been increasing again, amounting now to 22,000 wheels a year. In 1867, 100,000 had been cast, 200,000 in 1871, 300,000 in 1874, and 400,000 will probably have been cast by the beginning of next year. The wheels were furnished to thirty different railroad companies. The manufacture of railway crossings from the material is also an increasing industry. The depth of the chill of the wheel tread is from $\frac{3}{8}$ inch to nearly $\frac{5}{8}$ inch. Specimens of wheel sections are exhibited in the Paris Exhibition, and some old wheels, among which, one No. 423, has run 128,987$\frac{1}{2}$ miles, and another, No. 3684, has run 340,446$\frac{2}{10}$ miles, as certified to by the Mohacs-Fünfkirchen Railroad Company. They are both from under cars in light service, and hardly show any wear. Baron M. M. von Weber, in his report to the Government (Vienna, May 31, 1874), recommended chilled wheels for luggage trucks, as being more economical and safe; he states that there is but one-tenth as many accidents from the breaking of chilled wheels as from others.

The long talked of project of a railway across the island of Newfoundland has been revived by an Act of the Legislative Assembly proposing to grant an annual subsidy of £24,000 to any company which shall construct and maintain a railway across the island, in addition to granting liberal concessions of Crown lands. The argument is that such a road would not only open up immense deposits of copper, iron, coal; nickel, lead and other minerals, great pine and spruce forests, and vast tracts of rich land, capable of producing in abundance the finest quality of wheat, but would virtually bring America almost a thousand miles nearer Europe by making practicable the establishment of a line of steamers from St. John's, a point nearer to Great Britain than New York by almost that distance, while also avoiding the dangerous part of the voyage between New York and Cape Race. That a railway across Newfoundland would develope a large traffic is, says the *Railway Age*, unquestionable; that it would result in a considerable diversion of ocean travel from New York to St. John's is somewhat doubtful.

ENGINEERING STRUCTURES.

Cost of Maintenance of Highways in and around Paris.—From a late number of Annales des Ponts et Chaussees we make the following abstract of the report of M. Graeff, Inspector General of Bridges and Roads.

The government appropriation for this department for 1878 having been fixed at three million francs, M. Graeff calls attention to the fact that as the total estimate called for 7,578,471 francs there would remain a requisition upon the city for upwards of four and a half millions if the projected plans were executed.

The estimates of cost of this and former years show a gradual increase of cost of repairing each of the three kinds of road surface now in use: viz., pavement, asphalt and broken stone.

The cost of maintaining paving was from 1872 to 1875, 0f.48 per square meter, in 1876 it was 0f.51 and the estimate for 1878 is 0f.53.

For asphalt the cost from 1872 to 1875 was 1.f20 in 1876 1.f30 and estimated for 1878 at 1.f27 per square meter.

For broken stone (macadamized) roads from 1872 to 1875 the cost was 1f.80 in 1876 it was 2f.11 and is estimated for 1878 at 2 francs per square meter.

These figures show an advance in cost over previous years, except for the year 1876 in which the prices for asphalt and broken stone were slightly above the current estimates. It appears that the advanced prices are due to increased expense of both materials and labor.

The above estimates lead to the suggestion that pavement be substituted for the macadamized surfaces except in streets used mainly by pleasure carriages, but it is added it does not seem practicable to restrict the use of broken stone any further at present. Economy in this direction is only to be accomplished by securing the most durable road material.

In the meantime many of the streets need repairing. They are in general only in fair condition, and some are actually bad. It is estimated that keep the thoroughfares in normal condition $\frac{1}{35}$ of their total surface should be renewed, and it is to be regretted that the appropriation for the current year will allow a renewal of only $\frac{1}{72}$ of their entire surface.

Wire Rope Conveyance.—By M. Korting.—A system of aerial transit on suspended wire ropes, designed by Messrs. Bleichert and Otto, of Leipzig, has been established to connect the gasworks at Hanover with the neighboring coal station on the Hanover-Altenbeck railway, for the supply of coal to the works. The line crosses the Limmerstrasse and the river Ihme, and is about 625 yards in length. There are two iron-wire ropes, placed 5 feet 10 inches apart, and employed respectively for the carriage of loaded and of empty wagons. They cross the Limmerstrasse at a height of 23$\frac{1}{2}$ feet, and the river at about 30 feet. The cables are respectively 1.12 inch and 1 inch in diameter, and are constructed of wire of 4 millimeters, about $\frac{1}{6}$ inch, in diameter. They are supported on pulleys at intervals of 24 yards, except in crossing the river, on a span of 57 yards. Resting on pulleys, they are free to expand or contract. They are kept taut by weights of 5 tons and 4 tons respectively.

The wagons are drawn by means of a $\frac{9}{16}$ inch endless wire rope, supported on rollers at intervals of 60 yards, and driven by a six-horse steam engine at a speed of three miles per hour. The wagons are constructed of sheet-

iron, and are capable of holding three hectoliters, or 106 cubic feet of coal; they are suspended from the carrying ropes on two grooved wheels, one in advance of the other, between which the attachment of the wagon is made. The bodies of the wagons are swivelled, so that they may be easily emptied. They follow each other at intervals of about 60 yards. Allowing for delays, the quantity of coal carried at no time exceeds 180 tons per day of ten hours, and is frequently less, the average delivery being only 135 tons. The working charges are:

	£.	s.	d.
Seventeen men at 2*s.* 6*d.*......	2	2	6
One carpenter................	0	3	5
Coal for the engine...........	0	6	4
Oil, waste, &c................	0	0	5
Per day.............	£2	12	8

being at the rate of 4.67*d.* per ton of coal conveyed. The total first cost of the system amounted to £3,580, and the charge for interest, depreciation, and 15 per cent. for maintenance, is reckoned at 5.13*d.* per ton, making a total charge of 9.8*d.* per ton, the former cost being 1*s.* per ton.

Macadamized Roads.—Attention is being directed to the condition and mode of construction of macadamized roads in London. It is stated, and there seems reason for the statement, that the streets paved in this way deteriorate much more rapidly since the date of the adoption of the steam road roller than they did formerly. The reason for this is sought in the difference in the size of the pieces of stone now used and those used by M'Adam. M'Adam employed road material consisting of pieces not larger than would pass through a ring under 2 inches in diameter, but a large proportion of those now used are not less than double the weight of the pieces so measured. The stone was formerly broken by hand, but machinery does the work, so that the cost of breaking should not be the explanation of the increase in size, more especially as sand and gravel is now employed during the rolling of the newly laid metal for binding it together. This binding, it is argued, is only required in consequence of the increased size of metalling, and that is soon washed away, leaving the large stones loosened and easily removable. Hence it is said that the roads are soon now in holes because the metalling is too large. On the other hand it is argued that, as the roads are now pressed by the heavy steam roller in place of the wheels of ordinary vehicles and comparatively light rollers, larger stones are admissible. It, however, remains to be learned by roadmaking engineers who have the opportunity of observation, whether the roadway is really as solid after the steam roller, as is usually imagined, or whether the circular rollers do not leave it in a condition somewhat loose at least near the surface. It has also to be learned whether the alteration in the size of the metalling is attended with inferior results and whether breaking the stone so small originally is not simply helping the ultimate disintegration. It has also to be proved that the increase in the traffic is not the main cause of the increased wear of the roads. That the more rapid wear has noticeably taken place since the adoption of the steam rollers does not offer any argument against the use of the latter, inasmuch as the increase of traffic in the same time has in more districts been remarkable. There is reason, however, for believing that the use of more finely broken road metalling would, especially if mixed with a small quantity of, say, Northamptonshire blast furnace slag broken to a small size, when well rolled and compacted under the steam road roller, make a more durable road than is now made with large metalling and gravelly sand.

ORDNANCE AND NAVAL.

Telescopic Artillery Sights.—We understand that the French Government, being satisfied with the preliminary trials with the telescopic sights invented by Captain Scott, R.E., have purchased three instruments to enable them to carry out exhaustive trials. The object of his invention is:—(1) To enable the gunner to take aim at distances equal to the full range of the gun. (2) To dispense with the errors of fire due to the inclination of sights when the gun wheels are out of level. (3) To enable the gunner to correct errors in range and direction by infallible mechanical adjustments, instead of calculations based upon guesswork—good or bad according to the experience of the firer.

The Expenditure of Ammunition.—The *Russian Invalide* adds some facts to those published in the Moscow *Gazette*, concerning the expenditure of ammunition by the Russians. According to this account the Russian artillery used 204,923 charges, and the infantry and cavalry 10,057,764 cartridges, which are distributed as follows:—Field Artillery—1288 guns, 114,879 shells, 43,029 shrapnels, 1091 cases of grape shot; together, 158,999 charges, or 123.46 per gun. Siege Artillery—151 guns, 23,995 shells, 24,095 bombs, 4174 cases of grape shot; together, 52,264 charges, or 346.12 per gun. Small arms—65,000 Berdan rifles; 3,625,364 cartridges, or 45.75 each; 37,000 cavalry carbines; 1,251,764 or 33.72 each; 217,000 Kruka rifles, 5,692,120 or 26.22 each; 16,000 revolvers, 88,516 cartridges or 5.42 each; together, 335,000 small-arms of all descriptions, which discharged 10,057,764 cartridges, or 30 each. According to the *Russian Invalide*, the number of troops engaged in actual fighting was 282,000 infantry, 37,000 cavalry, or 319,000 men, with 1288 field guns, making 3.9 guns to 1000 men. The large number of cartridges, viz., 1,251,764 from 37,000 rifles, expended by the cavalry, demonstrates the important part played by the cavalry during marches, and in its employment as infantry on fields of battle. The Turks are reported to have lost, in Europe and Asia, nearly 150,000 dead or wounded, which would indicate that about sixty-seven cartridges were required to place one man *hors de combat*, taking no account of artillery. The proportion of rifle firing to artillery fire is as 49 to 1.

PALLISER ON PROJECTILES.—Sir W. Palliser has written a letter, suggested by the artillery experiments which have recently been carried out, in which he says that they uphold, to the satisfaction of all, the principles advocated by him during the last fifteen years in connection with iron plate penetration. These are:—(1) That the form of the projectile should be such that the pressure of the plate should be brought to bear gradually on the projectile: and (2), that the projectile should be composed of a substance which offers a great resistance to pressure. These principles sound childlike in their simplicity; still they were opposed to the received opinions of the day. In advocacy of the principles the writer says: "I applied them by making a pointed (technically an ogival-headed) projectile of common cast iron of a hard nature, which is further hardened and compressed by casting in a peculiar mold. The results of my invention were so great that the Government of the day ordered that these projectiles should be officially designated the 'Palliser Projectiles.' All that now remains to me of them is their name. I trust the writer of your article does not wish to rob me of that too, for he makes no allusion to it in connection with them. If by any process it were possible to impart to ogival-headed projectiles of steel, or of silver, or of gold, the same property of resisting pressure imparted to the cast iron in my projectiles, then a Palliser projectile of steel, silver, or gold would be produced which would, no doubt, give as good results as those of cast iron. Experience has shown that it is very difficult to impart this property with any certainty into steel in large masses, and that its existence cannot be proved excepting by trial in the same manner as the Austrian soldier-servant tried his master's lucifer matches and found them all good, to the officer's great disgust when he wished to light his candle in the night. It is possible that similar difficulties might be met with in the construction of silver or gold projectiles. But why should public money be wasted in this way when thoroughly reliable projectiles can be produced from cheap cast iron which do all that can be required of them—viz., which will penetrate as far as the gun has power to drive them? Moreover, these projectiles possess the valuable quality of separating themselves into many pieces in planes, as a rule parallel with, and at right angles to, the axis of the projectile." Notwithstanding the progress in artillery since these principles were first enunciated by Sir W. Palliser, he believes firmly in the superiority of his projectiles for penetrating iron plates, and holds that, provided his first principles be true, nothing will ever be produced to surpass them.

BOOK NOTICES.

A DESCRIPTIVE TREATISE OF MATHEMATICAL DRAWING INSTRUMENTS. Fifth Edition. By WM. FORD STANLEY. New York: E & F. N. Spon. Price $2.00. For sale by D. Van Nostrand.

A full description of all the implements employed by the draughtsman is certainly a useful book. Four editions of the book are in the hands of students in different parts of the world.

HISTOIRE NATIONALE DE LA MARINE. Par JULES TROUSSET. Paris: Libraire, M. Dreyfous. Price $4.00. For sale by D. Van Nostrand.

This voluminous history of the navies of Europe is quite fully illustrated with portraits and naval battle scenes. The pictures are of medium quality only. The typography is good enough and there is a good deal of it—nearly 800 pages of large royal octavo size.

HANDBOOK OF MODERN CHEMISTRY, ORGANIC AND INORGANIC. By Dr. MEYMOTT TIDY. London: J. & A. Churchill. Price $5.00. For sale by D Van Nostrand.

This large work is divided into three parts: non-metallic elements, metallic elements, and organic bodies.

It may be regarded as a compend of chemical reactions and of the resulting compounds. It is not a book for a student, but will prove of good service to the working chemist or to the instructor.

It is well printed, contains 776 pages of matter, but no illustrations.

EXPERIMENTAL RESEARCHES IN PURE, AP PLIED AND PHYSICAL CHEMISTRY. By E. FRANKLAND, D.C.L.; F.R.S. London: John Van Voorst. For sale by D. Van Nostrand. Price $15.00.

The eminence of the author will insure a cordial reception for this work. A portion of this volume has already found a place in standard scientific works, having been published in the chemical journals in separate memoirs during the past thirty years.

This book of 1030 pages presents the record of this author's labors down to the present time.

The typography, especially of the chemical formulas, is excellent.

THE ARTISAN. By ROBERT RIDDELL. Philadelphia: Claxton, Remsen & Haffelfinger. Price $5.00.

This is in an instruction book for the use of students. It is mainly a set of illustrative examples beginning with practical geometrical problems and leading up to designs for timber constructions of various kinds. There are forty full page plates of quarto size, and a page of text facing each plate.

Among other examples of a practical kind we find: Finding bevel cuts for splayed work; Butt-joints for acute Angles; Construction of High-Roofs; Construction of Niches; Platform Stairs; Hand-Railing, ets., etc.

The typography and plates are exceedingly good.

PROCEEDINGS OF THE INSTITUTION OF CIVIL ENGINEERS. Excerpt Minutes. Edited by JAMES FORREST, A.I.C.E., Secretary.

We have received through the kindness of Mr. Forrest the following papers of the Institution:

The Construction of Steam Boilers, adapted for very High Pressures, by James Fortescue Flannery.

Portland Cement Concrete, by John Watt Sandeman, M.I.C.E.

Portland Cement Concrete in Arches and Portland Cement Mortar, by Charles Colson, A.J.C.E.

A Skeleton Pontoon Bridge, by Bagot William Blood, M.J.C.E.

ANNUAL REPORT UPON THE SURVEY OF THE NORTHERN AND NORTHWESTERN LAKES, AND THE MISSISSIPPI RIVER. In charge of Gen'l C. B. COMSTOCK. Washington: Gov't Printing Office.

This is an Appendix to the Report of the Chief of Engineers for 1877. It contains four folding plates representing the systems of triangles about the great lakes, also four plates exhibiting by curves the changes of water level in the lakes separately.

Some detailed accounts of the measurements of a base line and of astronomical work will be especially interesting and instructive to students of geodetic surveying.

THE PHYSICAL SYSTEM OF THE UNIVERSE—AN OUTLINE OF PHYSIOGRAPHY. By SYDNEY B. J. SKERTCHLY, F.G.S. London: Daldy, Isbister & Co. For sale by D. Van Nostrand. Price $3.00.

The writer sums up in a careful way the evidence bearing upon the theories of Geology and Physical Geography.

The topics taken in order are, as presented by the author in chapters, are: I, Introduction; II, Matter and Motion; III, Light; IV, The Sidereal System; V, VI, and VII, The Solar System; VIII, The Sun; IX, X, The Earth's Internal Heat; XI, and XII, The Earth's External Heat; XIII, Climate; XIV, Life; XV, The Nebular Hypothesis.

EXAMPLES OF MODERN STEAM, AIR AND GAS ENGINES. By JOHN BOURNE, C.E. London: Longmans, Green & Dyer. For sale by D. Van Nostrand. Price $30.00.

This work was begun some few years since and issued in parts, each part being a quarto with generally a folding plate and several large wood cuts interspersed in the text. After a long interruption to the publication, the final parts have appeared, and the work as completed is a large quarto with fifty plates and about 400 wood cuts.

The illustrations are so complete as to details that the explanatory text is scarcely necessary. The plates are in most cases "working drawings," and all moderm improvements are discussed.

DICTIONNAIRE DE CHIMIE. PURE ET APPLIQUEE. Par AD. WURTZ. Paris: Libraire Hachette et Cie. For sale by D. Van Nostrand.

This Dictionary is now complete. It includes Organic and Inorganic Chemistry; their applications to manufactures, agriculture, and the arts; also their bearing upon Physics, Mineralogy and upon Physical and Chemical research.

No pains have been spared to present topics with a proper degree of fullness and pictorial illustration.

References to the sources from whence the articles have been condensed are given with satisfactory completeness.

In these days of rapid advance in Applied Chemistry, such a compend of Chemical Processes is to the Analyst or Manufacturing Chemist indispensable.

REPORT ON BRIDGING OF THE RIVER MISSISSIPPI BETWEEN SAINT PAUL, MINN., AND ST. LOUIS, MO.—By Brevet Major General G. K. WARREN,—Major of Engineers. 232 pp. 8vo., with many maps. Washington, 1878. For sale by D. Van Nostrand.

The report on bridging the Mississippi River between St. Paul, Minn., and St. Louis Mo., by Gen. G. K. Warren, is a very valuable contribution upon the subject of bridging navigable waters. Ordinarily, bridges have been constructed for highways and railroads, only in the interest of the companies building them, and with little or no attention to the interests of navigation. In all cases where there has been a considerable amount of water traffic, it is true that the companies have been compelled to build draws, but these have often been very badly situated and of difficult and dangerous passing, and it was only when the navigation interests of a great public highway like the Mississippi became involved that sufficient influence was brought to bear upon the question to protect the navigation from unnecessary obstruction by the bridges that must inevitably be built. The matter was brought before Congress, and General Warren was appointed to make the necessary examinations, and report. The interests involved in the construction of railway bridges over the Mississippi and other large navigable channels are diametrically in opposition. On the one side, the railway companies desire to build bridges on the grade of their road, in the best line for them across the stream, and wish the most economical spans; and almost invariably prefer a low structure with a draw, rather than construct a high bridge under which steamboats can pass. On the other side, the river traffic demands bridges at right angles to the current, with piers in its exact direction, wide spans, and a superstructure which any boat navigating the river can pass under at high water. It was chiefly with a view to determine how these conflicting interests could be reconciled, that the investigations conducted by General Warren were ordered by Congress. The duty assigned to him has been admirably performed. He appears to have impartially considered the rights of all parties, and to have brought a vast amount of keen observation and practical good sense to bear upon the questions involved. He appears to have considered the subject in all its engineering, commercial, financial and legal bearings, and to have collected data and documents to support his deductions, so that any one reading his report can see the reasons upon which he bases his conclusions.

Gen. Warren commences by stating the origin and nature of the investigation, and gives a general description of the Mississippi valley in connection with that of the Minnesota river. He considers the geographical structure of the

region embraced by the report, and advances the hypothesis, previously more fully set forth in his report upon the Minnesota River (Report of Chief of Engineers, 1875) that the water from Lake Winnipeg once flowed southward into the Mississippi through the Minnesota valley. There seems from his statements no good reason to doubt the correctness of his theory. He next gives a general presentation of the requirements and advantages of western river navigation, the necessity for wide spans and high bridges, and a discussion of the data for determining the headway required. He then gives a description, with maps and diagrams showing the location and character of the several bridges that have been constructed between St. Louis and St. Paul; likewise showing the direction of the river current through the openings between the piers. A comparison of these in the different bridges is very interesting. One of the bridges described, the new bridge at Rockland, was designed and located, as well as partially constructed under his immediate direction. He then goes on to give a general history of bridging the navigable western rivers, in its relations to the laws, to the decisions of the United States Courts, and the debates in Congress. He also gives the opinions of many eminent engineers with relation to the length of spans practicable and other points of interest. He concludes with an acccount of the manner in which his examinations have been made. The whole report shows the utmost attention to facts and details of value for future reference, and represents the immense amount of work performed by General Warren and his assistants.

As an engineering essay upon the location and general character of bridges over large navigable streams it is of great value to the profession, both on account of the numerous examples given with their advantages and defects, and the plain statement of the principles involved and which are as applicable to other streams as to those described.

GRAPHICAL STATICS. By A. JAY DUBOIS. (A communication from the author.)

DEAR SIR:—I notice in the November No. of the MAGAZINE a criticism upon the first edition of my "Graphical Statics," translated from the *Zeitschrift des Ver. Deutsch, Ing.* The extract is but a partial one, and it seems, to me, at least, somewhat unjust that the few surly and grudging words of commendation which the author of the critique felt obliged to give me for a work of great labor, evidently much against his will, should have been entirely omitted by your translator, and only his animadversion given to the public.

With an honestly written and intended criticism, whether complimentary or the reverse, I have not, however, and never shall have, fault to find, and certainly shall not take it upon me to answer. The same holds good for the malicious attacks of personal hostility. Witness: A criticism which appeared in your own columns in February of this year, the tone and tenor of which were so personal and malicious that it was beneath contempt, and formed its own best reply. Small wonder that it went begging acceptance of respectable journals until it finally found a lodgment in your columns. If my work is not its own best defense from such palpable attacks, little that I could say, even were I willing to say it, would have any effect.

When, however, a specific charge of dishonesty is made, I consider it my duty to meet it squarely and brand it as slander.

The charge is as follows: "The American reader is led to infer from DuBois' method of reference that only one page of his Introduction is taken from Weyrauch; when, in fact, as I find after a thorough examination, there are twenty-seven pages of close translation." This I brand as a slander, and I wish to call public attention to its entire lack of foundation, and the source from whence it emanates. I will do its author the justice to suppose that it is unintentional and due more to ignorance of the English language, or, perhaps, to natural stupidity, rather than to real malevolence. If not malevolent, however, it is certainly very stupid and very conceited. If, instead of the words "American reader," the critic had spoken for himself alone, he would at least not have been guilty of the conceit of supposing the American reader as stupid as himself.

It is, at best, a very stupid error, and considering the gravity of the charge, an unpardonable one. No acknowledgment could possibly be fuller than that which I have made. I state in the Preface that I am indebted for the Introduction, with few alterations, to Prof. Weyrauch, and I give the full title of the brochure translated. That the astute critic cannot find any alterations does not prove their non-existence, but rather illustrates still more forcibly his cast iron "*dumbness.*" Not content with this acknowledgment in the Preface, which certainly covers the Introduction sufficiently, I have, upon the first page of the Introduction, refreshed the memory of the reader by a foot-note again referring to the original. This is the "method of reference" which misleads, according to our wiseacre, American readers!

Again, the "first page," which seems to bother him so, closes as follows: "We have, therefore, to ask of the reader who wishes to obtain a just and accurate estimate of this new, and, as we venture to think, highly important subject, patience for the following general consideration." Then follows in succeeding pages these considerations. It has remained for our sagacious German critic to make the discovery that all this acknowledgment refers only to the "first page," in spite of the context as given above!

It is much to his credit that no one else has ever been accurate enough to make this astonishing discovery, not even the "American reader," who will even find difficulty in seeing it when pointed out. As to Prof. Weyrauch, who ought certainly to be the best judge of what is due himself—he has expressed himself as highly pleased and gratified. But then he is not an "American reader," or rather, he is a much better one than our critic. My intimacy with him justifies me in the promise that he will himself answer in my behalf, over his own

name, this accusation in the JOURNAL, where it originated, when, *of course*, you, Mr. Editor, will be only too delighted to translate it also for the benefit of the much enduring "American reader."

When I add that Prof. Weyrauch's little pamphlet is of popular interest, that it was received by me while the book itself was in press and inserted by way of a popular introduction, and that it is entirely separate and apart from the body of the work, with which it has nothing whatever to do, I am sure this same "American reader" will be lost in admiration at the amiable temper of our critic, and will wonder at the acuteness which discovered so much—which has no connection whatever with the book proper, to growl about.

I have stated in my Preface, and wish to repeat here, once for all, that I have indicated fully all obligations, and have been glad to do so, as much for my own credit as for the advantage of the student. Such references are not as frequent in many works of higher pretensions as they might or ought to be. I have yet to learn of any dissatisfaction with my "method of reference" from those concerned. On the contrary, the kind expressions I have received are a sufficient answer to any such imaginary charges from incompetent sources. The critic's incompetency peeps out in many places. For instance, he insinuates doubt as to the thoroughness of my study of "Favaro and others." Considering that Favaro appeared later and has studied and acknowledged indebtedness to me, I am inclined to the same suspicion as regards our German friend.

The sum total is, that, with considerable labor and a pretty fair knowledge of my subject, I have produced a work which, whatever its demerits, can at least lay claim to honest intention and execution, and which is not devoid of original merit. I would, therefore, state, once for all, that any imputations upon my honesty must not be based upon my work, or it will be at the risk of the accuser, and may possibly end in putting him in an unenviable situation as regards his own honesty of purpose.

A. J. DU BOIS.

MISCELLANEOUS.

THE POPULATION OF THE EARTH.—The fifth publication of Behm and Wagner's well-known "Bevolkerung der Erde," is just out, giving some elaborate statistics on this subject.

Since the last publication of these statistics the population of the earth shows a total increase of 15 millions, partly arising from natural growth and partly the outcome of new and more exact censuses. The total population is now set down at 1,439,145,300, divided among the Continents as follows:—Europe, 312,398,480; Asia, 831 millions; Africa, 205,219,500; Australia and Polynesia, 4,411,300; America, 88,116,000. The following table gives the latest results for the chief countries in the world:—

EUROPE.	
Germany, 1875	42,727,360
Austria-Hungary, 1876	37,350,000
Liechtenstein, 1876	8,664
Switzerland, 1876	2,759,854
Netherlands, 1876	3,865,456
Luxembourg, 1875	205,158
European Russia, 1872	72,392,770
Finland, 1875	1,912,647
Sweden, 1876	4,429,713
Norway, 1875	1,807,555
Denmark, 1876	1,903,000
Belgium, 1876	5,336,185
France, 1876	36,905,788
Great Britain, 1878	34,242,966
Faroes, 1876	10,600
Iceland, 1876	71,300
Spain (without Canaries), 1871	16,526,511
Andorra	12,000
Gibraltar, 1873	25,143
Portugal (with Azores), 1875	4,319,284
Italy, 1876	27,769,475
European Turkey (before division)	9,573,000
Roumania, 1873	5,073,000
Servia, 1876	1,366,923
Montenegro	185,000
Greece, 1870	1,457,894
Malta, 1873	145,604
ASIA.	
Siberia, 1873	3,440,362
Russian Central Asia	4,505,876
Turcoman Region	175,000
Khiva	700,000
Bokhara	2,030,000
Karategin	100,000
Caucasia, 1876	5,391,744
Asiatic Turkey	17,880,000
Samos, 1877	35,878
Arabia (independent)	3,700,000
Aden, 1872	22,707
Persia	6,000,000
Afghanistan	4,000,000
Kafiristan	300,000
Beloochistan	350,000
China proper	405,000,000
Chinese border lands, including Eastern Turkestan & Djungaria	29,580,000
Hongkong, 1876	139,144
Macao, 1871	71,834
Japan, 1874	33,623,373
British India within British Burmah, 1872	188,421,264
Native States	48,110,200
Himalaya States	3,300,000
French Settlements, 1875	271,460
Portuguese do. do	444,617
Ceylon, 1875	2,459,542
Laccadives and Maldives	156,800
British Burmah, 1871	2,747,148
Manipur	126,000
Burmah	4,000,000
Siam	5,750,000
Annam	21,000,000
French Cochin China, 1875	1,600,000
Cambodia	890,000
Malacca (independent)	290,000
Straits Settlements	308,097
East Indian Islands	34,051,900
AUSTRALIA, &C.	
New South Wales, 1876	630,843
Victoria, 1876	841,938
South Australia, 1876	229,630
Queensland, 1876	187,100
West Australia, 1876	27,321
Tasmania, 1876	105,484
New Zealand and Chatham, 1876	444,545
Rest of Polynesia	1,896,090

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Charles Frederic Hartt, Professor of Geology in the Cornell University, and Chief of the Geological Commission of Brazil, died on the eighteenth of March last, in Rio de Janeiro, where he was engaged in preparing the reports of his Survey.

His death and the dissolution of the Commission, of which he was the founder and director, have prevented the realization in Brazil of the plan of surveying proposed in the accompanying pages.

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